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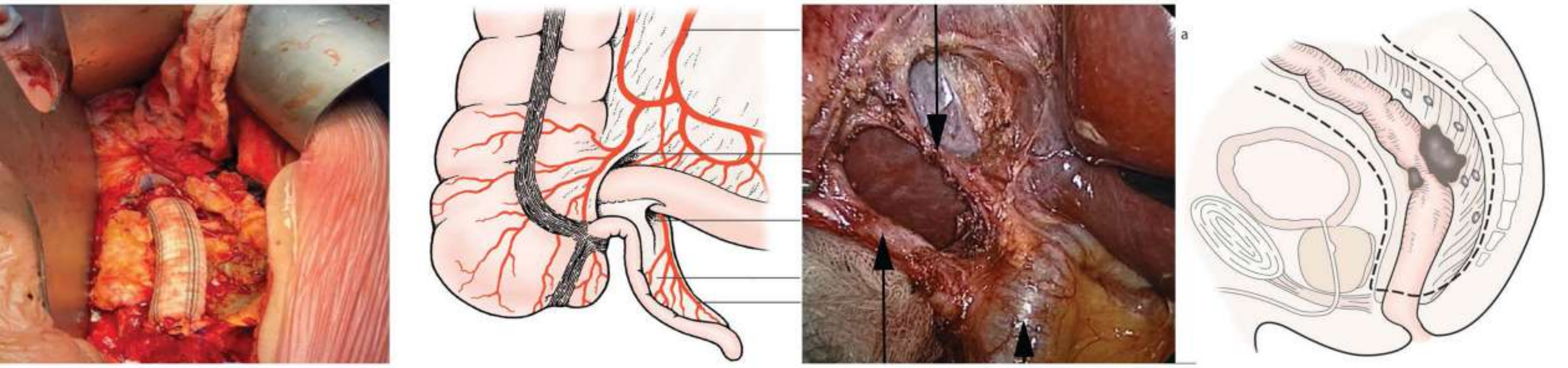
ELEVENTH EDITION

FARQUHARSON'S
TEXTBOOK OF OPERATIVE GENERAL SURGERY



Brendan Moran
Rohin Mittal
Amy Lord

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FARQUHARSON'S
TEXTBOOK OF OPERATIVE GENERAL SURGERY

The Eleventh Edition of *Farquharson's* continues to provide both the fundamental surgical skills needed by junior trainee surgeons and the general surgical subspecialty knowledge necessary for higher surgical training. The topics cover the whole patient, based on the concept that trainee surgeons need an overview and all surgeons need to occasionally operate outside their area of expertise.

Although surgeons in training no longer anticipate that they will be expected to undertake unfamiliar operations without supervision, disease and injury do not respect specialty organ practice, especially in emergency surgery and trauma. With increasing specialisation, even experienced surgeons can sometimes be involved in a surgical emergency or an intraoperative complication, requiring them to perform an operative procedure in a subspecialty other than their own. With this in mind, each of the specialist authors has focused their topic on principles for the general surgeon, and the editors have consolidated and adapted the information to bridge the gap between general and specialty surgery.

In many parts of the world, General Surgery has remained an all-encompassing surgical discipline and, in remote hospitals, General Surgeons may be the only surgical specialists. When transfer and referral options are unavailable, or delayed, these surgeons may have to offer a limited service in orthopaedics, neurosurgery, urology and obstetrics. For these reasons, some operations in other surgical disciplines are included, and here the emphasis is more on what might be achievable in difficult circumstances, rather than on a more sophisticated procedure, if this would be impractical outside a specialist centre.

This classic concise textbook will benefit all General Surgeons, whether already well established or just embarking on their career in surgery.

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ELEVENTH EDITION

FARQUHARSON'S
TEXTBOOK OF OPERATIVE GENERAL SURGERY

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PREFACE TO THE ELEVENTH EDITION

Surgery, by definition, always has, and always will be, fundamentally operative by nature and, while instrumentation may progress, the surgeon is at the heart of the intervention. The recent modern developments in laparoscopic and robotic technology are a prime example of technological advances, but ‘laparoscopes and robots don’t operate; surgeons do’. The surgeon often helps to design, and develop, the operative technology and is the interface between technology and the patient. As surgeons, we have to constantly promote and embrace change but maintain the fundamental operative principles. The origins of the term ‘surgery’ come from ancient Greek and Latin, and it literally translates to ‘hand work’. While instrumentation may advance, the fundamental skill is technical precision incorporating knowledge, training and experience.

Eric Farquharson was a young consultant general surgeon when *Operative Surgery* was first published in 1954, and the subsequent editions have evolved to incorporate increasing subspecialisation in surgery, such that the current eleventh edition is now a multiauthor textbook. Each of the specialist authors has focused their topic on principles for the general surgeon and, as editors, we have consolidated and adapted the information to bridge the gap between general and specialty surgery. This book addresses the key role of general surgeons, namely the main first-line deliverers of emergency and trauma care. The topics cover the whole patient, based on the concept that trainee surgeons need an overview and all surgeons need to occasionally operate outside their area of expertise. Disease and injury do not respect specialty organ practice, especially in emergency surgery and trauma.

The focus of this book is to describe the anatomy and operative details and to guide decision-making when there is a choice of surgical options. Whilst we anticipate that surgical trainees will find this overview a useful manual as they learn and experience surgery in its broadest extent, we envisage that the book would be readily available in the operating theatre and of value to the practising general surgeon.

The book has been extensively updated with the involvement of many surgical specialists. All of the common operations in the general surgical subspecialties that are likely to be encountered during higher surgical training are described and, additionally, basic techniques are explained for the junior trainee. Although surgeons in training no longer anticipate that they will be expected to undertake unfamiliar operations without supervision, unforeseen circumstances can still arise. With increasing specialisation, even experienced surgeons can sometimes be involved in a surgical emergency or an intraoperative complication, requiring them to perform an operative procedure in a subspecialty other than their own.

Some references are provided at the end of each chapter, but no attempt has been made to provide a comprehensive bibliography and, indeed, a number are of historical relevance.

In many parts of the world, General Surgery has remained an all-encompassing surgical discipline and, in remote hospitals, General Surgeons may be the only surgical specialists. When transfer and referral options are unavailable, or delayed, these surgeons may have to offer a limited service in orthopaedics, neurosurgery, urology and obstetrics. For this reason, some operations in other surgical disciplines are included, and here the emphasis is more on what might be achievable in difficult circumstances, rather than on a more sophisticated procedure, if this would be impractical outside a specialist centre.

We hope that this classic textbook will remain of value to General Surgeons, whether already well established in surgery or just embarking on a surgical career.

Brendan Moran

ABOUT THE EDITORS

Brendan Moran

Brendan Moran is Consultant General and Colorectal Surgeon in Basingstoke, UK; Honorary Professor of Surgery in the University of Sydney, Australia; and Honorary Senior Lecturer, Cancer Sciences Division, Southampton, UK. He trained in surgery in Ireland between 1980 and 1984 and spent 18 months in Ghana, West Africa, in 1985–1986. In Ghana, he found that *Farquharson's Textbook of Operative Surgery*, the only textbook that he carried with him, was invaluable, and he left the copy in Holy Family Hospital, Techiman, Ghana. When training and working in Basingstoke in the 1990s, he worked with Margaret Farquharson, Consultant General Surgeon, and persuaded Margaret that they should embark on re-editing what became the ninth edition. Brendan, Margaret and Margaret's son, James Hollingshead, edited the tenth edition.

Brendan's main interests are in rectal cancer and peritoneal malignancy. He has developed and led national and international multidisciplinary workshops in the surgery for rectal cancer over the past 20 years and continues to do so with the current Pelican OReCO (Optimising Rectal Cancer Outcomes) UK and Ireland programme. He has popularised the concept that 'decisions are more important than incisions', suggesting that case election and precision surgery are the key to the best outcomes in all aspects of surgery.

Brendan established the Peritoneal Malignancy Institute, Basingstoke, which has expanded to be the largest centre in the world in the treatment of disseminated appendix tumours and other peritoneal malignancy, particularly colorectal peritoneal metastases.

Brendan considers it a great privilege to be able to continue a classical textbook outlining the fundamental principles of safe general surgery, principles that change little despite major technological advances in imaging and in laparoscopic and robotic instruments.

Rohin Mittal

Rohin Mittal is a Consultant Colorectal and General Surgeon and the Clinical Lead of the Colorectal Surgery Unit at Christian Medical College, Vellore, India. He completed his surgical training at CMC Vellore in India and pursued advanced fellowships in the United Kingdom at Colchester General Hospital and the Peritoneal Malignancy Institute in Basingstoke, as well as in the United States at the Ferguson Clinic in Grand Rapids, Michigan.

Rohin established the Colorectal Peritoneal Malignancy Programme at CMC, Vellore and has a keen interest in enhancing the quality of cancer care and establishing MDT-based practice. He is involved in setting up and running the monthly national GI cancer MDT in India. He is also a member of the GI Cancer Guideline Development Group of the National Cancer Grid, India.

Rohin also serves as the Director of the South India sub-hub for the NIHR Global Health Research Unit on Global Surgery. This collaboration aims to create a network of surgeons to promote research and address locally relevant questions through regional studies, particularly in resource-limited settings. His other research interests include integrating bench and clinical research. To achieve this goal, he has collaborated with various departments to explore the roles of the microbiome, genome and novel biomarkers in the causation, diagnosis, treatment and prognosis of colorectal cancer.

Rohin is honoured to edit the latest edition of *Farquharson's Textbook of Operative General Surgery*, which he used extensively during his training. This book remains a key resource for young surgeons, providing the fundamentals of operative general surgery – essential building blocks for a solid surgical foundation.

Amy Lord

Amy Lord is Consultant Colorectal Surgeon in Basingstoke, UK, and serves as Research and Education Lead for the Pelican Cancer Foundation. She also holds an honorary position as Senior Clinical Lecturer at Imperial College London. Amy completed her general surgical training across the London and Wessex Deaneries, followed by Post-Certificate of Completion of Training Fellowships at Frimley Park Hospital, UK, and the internationally recognised Peritoneal Malignancy Unit in Basingstoke.

Amy is passionate about research to advance cancer care and earned her PhD at Imperial College London and the Royal Marsden Hospital, London, under the supervision of Professor Gina Brown. Her research focuses on the diagnosis and staging of rectal cancer, particularly the role of radiological assessment in identifying tumour deposits – work that is helping to shape staging and prognostication practices. She continues her academic collaboration with the Imperial team through projects such as the MERCURY 3 trial, which seeks to transform how rectal cancer is staged using magnetic resonance imaging.

Amy also co-leads the national Pelican OReCO programme with Brendan Moran, aiming to improve multidisciplinary decision-making in rectal cancer management across the UK.

Amy is honoured to continue the legacy of Margaret Farquharson, Basingstoke's first female colorectal surgeon, by contributing to the latest edition of this important and comprehensive surgical textbook. She acknowledges the trailblazing efforts of the women who came before her, whose determination opened doors and made it possible for the next generation of female surgeons to be seen, respected and heard in the profession.

CONTRIBUTORS AND ACKNOWLEDGEMENTS

All chapters have been extensively updated for this edition, and some chapters have passed through as many as six different specialists. We thank all of the contributors for the time and effort that they have given to this project. Some have had major involvement in one or two chapters, whereas other contributors have been involved in parts of almost every chapter in the book. All contributors are listed below.

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1

Basic surgical skills and techniques

Amy Lord and Rohin Mittal

SURGICAL SKILLS

Technical skills are a key part of surgical practice, and their acquisition is generally the main focus of surgical training programmes and a preoccupation for trainees throughout the world. Traditional core skills, such as suturing and knot tying, can be learnt and practised in a simulated environment as part of courses such as 'Basic Surgical Skills' run by the UK surgical colleges and by many surgical societies across the world. There are increasing opportunities for simulation training with evolving technology, ranging from box trainers to simulate laparoscopic surgery to virtual reality and high-fidelity robotic platforms in more recent years.

Although good technique is important, it must be remembered that effective surgical practice also includes more than the operation itself: diagnostic skills and investigation of pathology that might require surgical intervention, as well as decisions as to what surgery should be advised and whether surgery is appropriate at all, have at least equal importance. Good surgical practice also includes the preoperative and postoperative care of the surgical patient, with particular attention to patient safety. Likewise, operative surgery is more than just a technical challenge and requires preoperative, intraoperative and postoperative decision-making skills. It is important to remember that one of the most crucial operative skills to develop is the ability to make sound intraoperative decisions.[1,2] Not every operation proceeds according to plan, and often alternative strategies have to be devised intraoperatively.

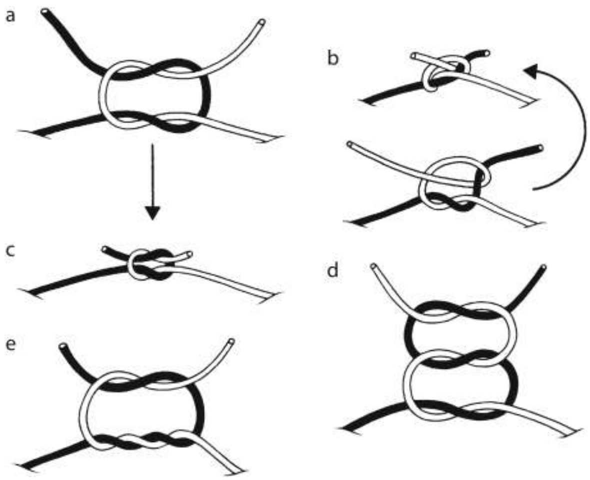
BASIC TECHNICAL SKILLS

KNOTS, LIGATURES AND SUTURES

Knots

The first skill a trainee surgeon must master is the ability to tie secure knots. The simple and reliable reef knot is well known and is universally advocated for surgical purposes (Figure 1.1). A *triple* knot is the modification of the reef knot commonly used, and at least three throws are required for security. With slippery monofilament material, multiple throws are required to provide a safe knot, and the ends should not be cut too short. Extra turns in all throws or just the first throw (often known as a surgeon's knot) can give added security, especially to a knot of thicker monofilament material.

Knots may be tied using the needle holder to grasp the end of the suture material, which must be wound around the instrument in the opposite direction on the second throw to achieve a reef knot (Figure 1.2).



1.1 Different types of knots. (a) A reef knot: this must be kept 'square' by tightening in the correct directions and with equal tension on the ends. (b) A reef knot that has been spoiled by careless tightening so that an insecure knot results: the white strand has been pulled to the left. (c) The white strand has been correctly pulled to the right and the black to the left; see (a). (d) A triple knot. (e) A surgeon's knot with an extra turn on the first loop. ⏎

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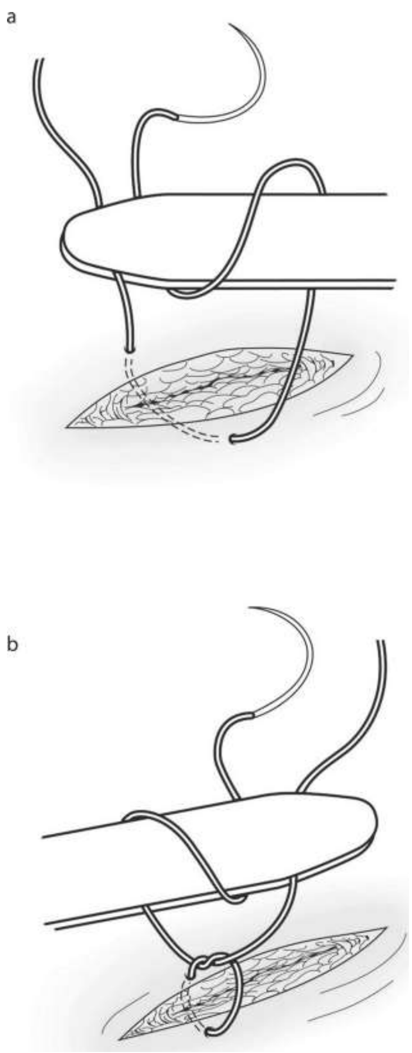
This method is suitable for tying the knots of skin sutures and is also used for the knots in laparoscopic surgery, which have to be executed entirely by instrument tie. In open surgery, a hand-tying technique is often preferred for tying the knot of a ligature or of a deep suture, as it is felt that it allows better control of tension and could potentially be more secure. The left-hand technique is shown in Figure 1.3. It is important to remember that whichever method is used, if a reef knot is not kept 'square', an insecure 'slip knot' results. In a deep wound, the index finger of the left hand is used after each throw to settle the new throw onto the previous throw and to tighten the knot.

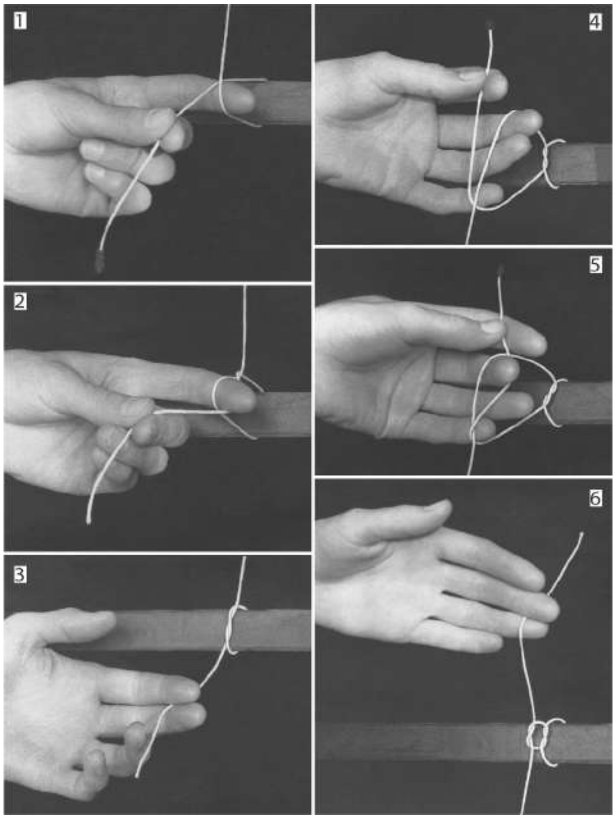
At the end of a continuous suture (e.g. closure of the abdominal wall), the surgeon is left to tie a 'loop' to an 'end', which is not ideal, especially in slippery monofilament material. The Aberdeen knot (Figure 1.4) is useful in this situation.

Ligatures

The time-honoured method of closing a divided blood vessel is with a ligature. A small vessel may have been cut during dissection and the bleeding point picked up with artery forceps. Other vessels may have been secured before division between artery forceps. The vessel should be isolated and cleared of surrounding tissue as far as possible, as including a mass of tissue in the artery forceps can make secure ligation more difficult. For the 'tying off' or ligation of vessels, close cooperation between the surgeon and assistant

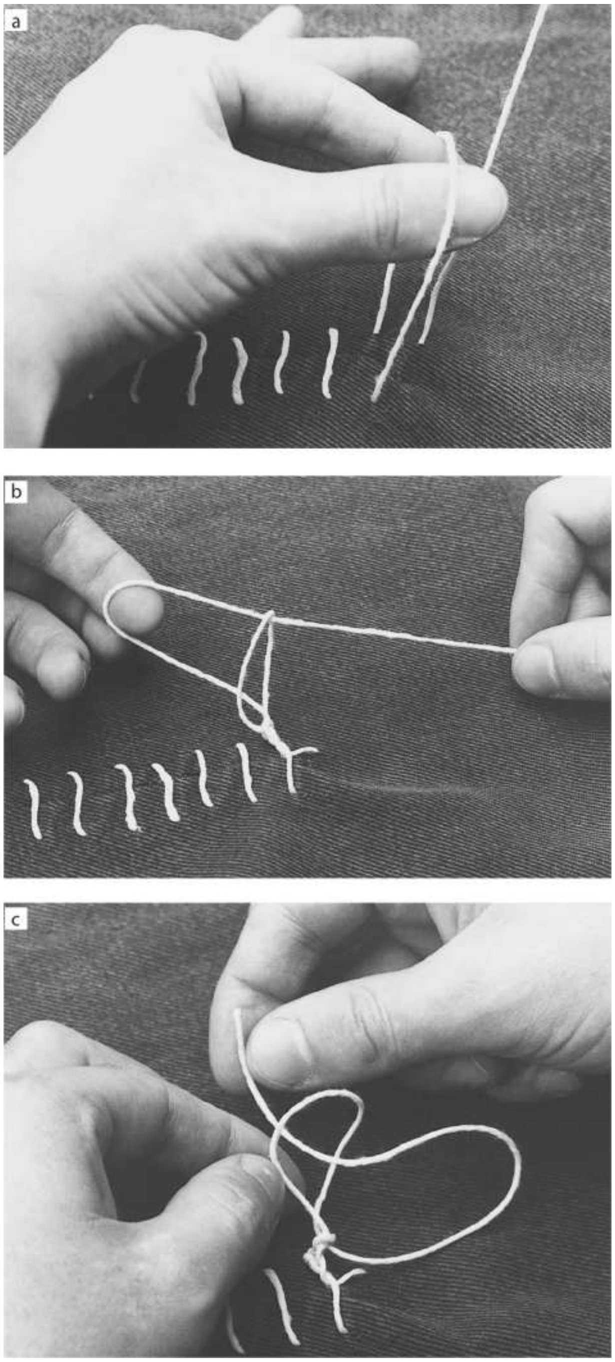


1.2 An instrument tie. Note that the suture material is wound in the opposite direction in the second throw to achieve a reef knot. The direction of pull on the suture ends must also be reversed for each throw in order to keep the knot square. ⏎



1.3 Method of tying a reef knot with the left hand. Note how the knot is kept 'square' by tightening in the correct directions (the end of the suture material passing off the edge of each photograph is held in the right hand). This is an original illustration from the 1954 edition. The photographs were taken by Eric Farquharson himself of knot tying by his wife. As illustrated, knot tying can be practised using any material and any fixed object, such as a chair. ⏎

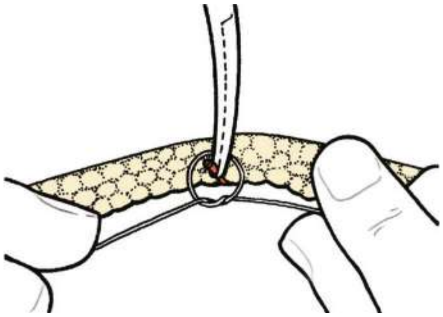
is required. The surgeon passes the ligature material around the forceps, while the assistant holds the forceps, depressing the handle and elevating the point as much as possible, so that the tissue that is clamped is encircled by the ligature (Figure 1.5). Just as the surgeon is tightening the first hitch of the knot, the assistant slowly releases the forceps. Sudden release of the forceps should be avoided, as the blood vessel is liable to slip out of the grasp of the ligature. Every time a vessel is ligated, two ‘foreign bodies’ are introduced: the ligature itself and the strangulated tissue beyond it. It is therefore important to include as little adjacent tissue as possible in the clamp, to use the finest material consistent with security and to not leave the cut ends longer than necessary.



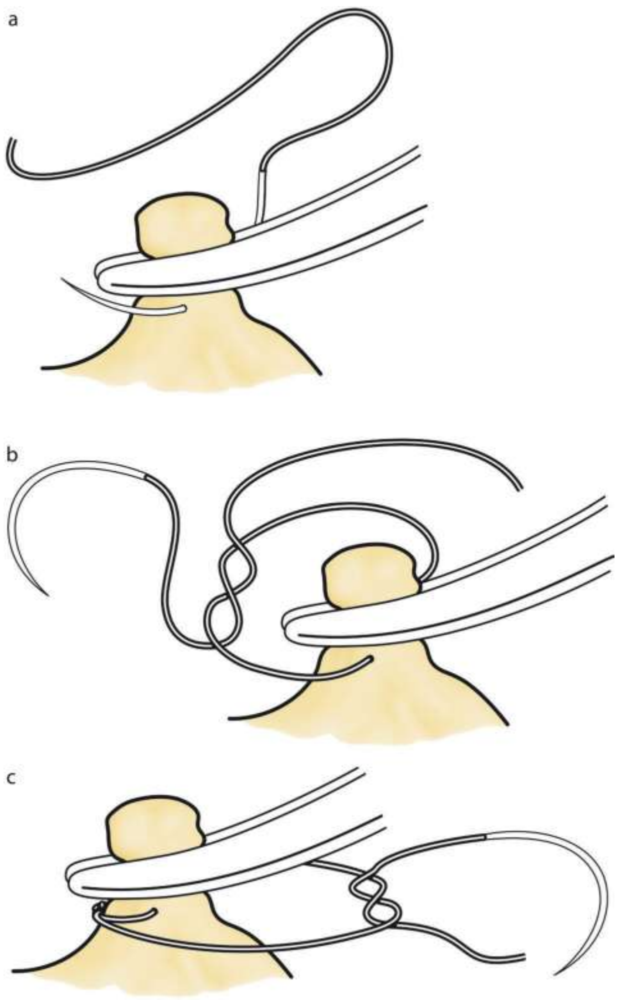
1.4 The Aberdeen knot. (a) After the last suture has been inserted, it is drawn through until there is only a small loop. The surgeon passes an index finger and thumb through the loop to grasp the suture and pull it through to form the next loop. (b) As each new loop is formed, the previous loop is allowed to close to form the next layer of the knot. (c) Finally, the end of the suture – rather than a loop of it – is passed through the loop and the knot tightened. ⏎

If artery forceps have been applied to a bleeding point in such a way that it is difficult for the assistant to elevate the point, simple ligation is unlikely to be secure. A short, wide vessel stump poses similar concerns over security. Transfixion ligation is then safer (Figure 1.6). The surgeon passes the suture needle under the forceps through the middle portion of the grasped tissue. The first throw of a knot is then formed and this loop is settled deep to the points of the artery forceps to encircle half of the tissue. The ligature is then passed round, under the handle of the forceps, to encircle the other half of the tissue and again the first throw of a knot is formed. As the surgeon tightens this first throw, and therefore the whole figure-of-eight ligature, the assistant slowly releases the artery forceps. An even safer transfixion suture favoured by some surgeons is shown in Figure 1.7. In this, the needle is passed a second time through the tissue held in the artery forceps, with the loop of suture material passing under the tips of the forceps. The figure-of-eight is then completed by the knot tied under the handles. These transfixion sutures have greater application in securing major vessels. Occasionally, transfixion ligation of a short stump is unsuitable if it will narrow the underlying more major vessel. A sutured closure is then more appropriate.

Sometimes, a thin-walled, wide and therefore easily torn vein can be dealt with more safely by passing a ligature above and below the point of intended division and only dividing the vessel after both ligatures are tied (Figure 1.8). Artery forceps are first passed carefully under the vessel and the jaws opened



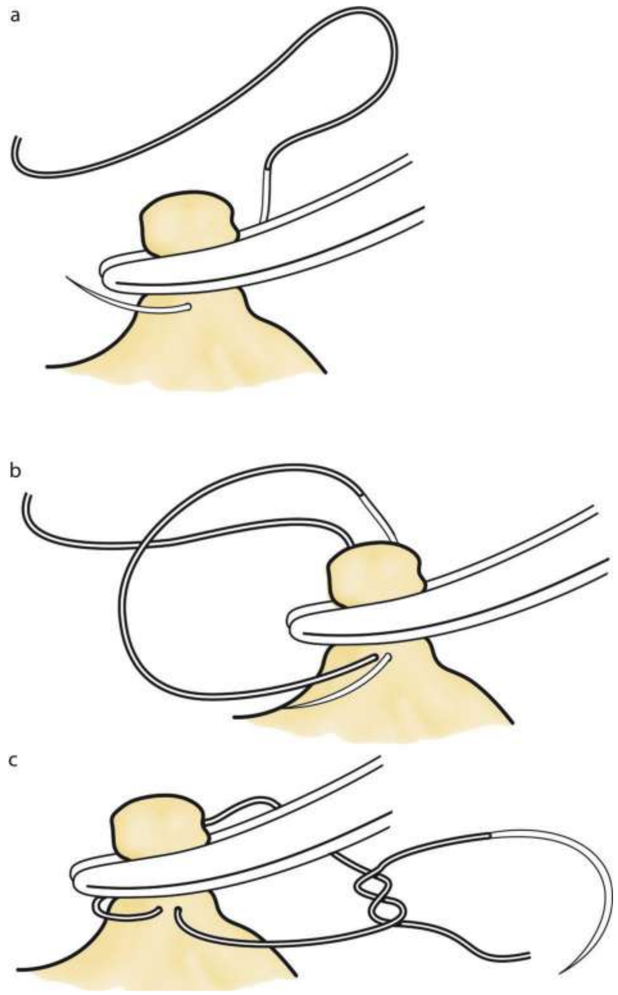
1.5 Method of ‘tying off’ a bleeding point. ⏎



1.6 A transfixion suture. The figure-of-eight ligature is prevented from slipping off by its anchorage through the tissue. ⏎

sufficiently to grasp the ligature material, which is carried to the open jaws by a second pair of artery forceps – a '*mounted* tie' (Figure 1.8a). The ligature is then drawn round under the vessel.

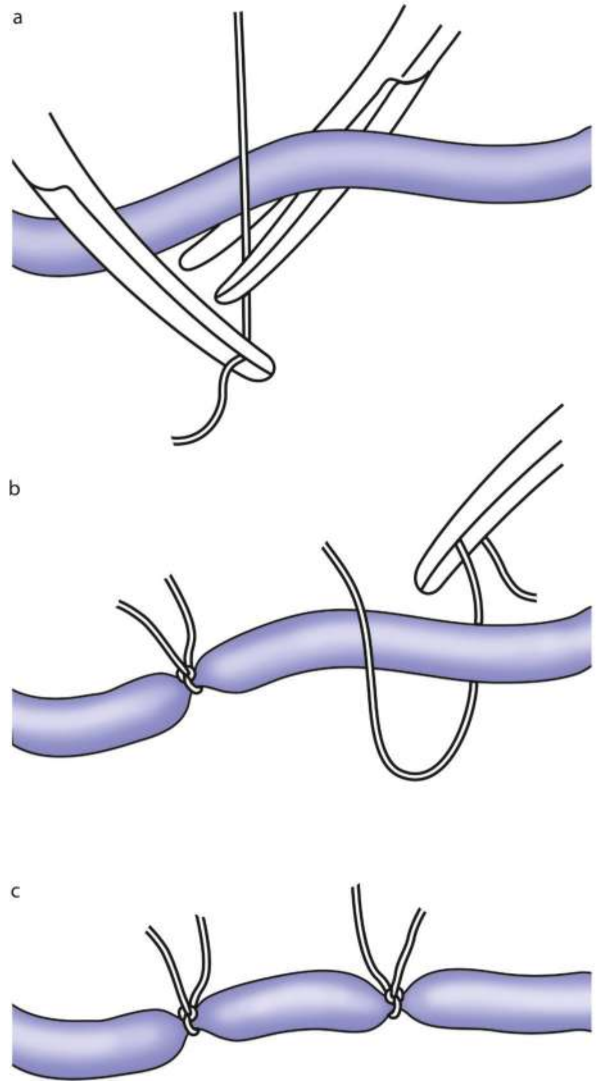
Coagulation diathermy is an alternative to ligation for sealing small blood vessels. A vessel may be coagulated before division or after it has been clamped and divided. It can also be coagulated when it has been identified as a bleeding point in the dissection plane. When using bipolar diathermy, the vessel is held in the diathermy forceps and the current passes from one point of the forceps to the other, coagulating and sealing the vessel held between them. When using monopolar diathermy, a vessel can be either picked up in the diathermy forceps and coagulated or secured first with artery forceps and the diathermy current passed down the artery forceps from the diathermy wand. Extra tissue held in forceps leads to less effective coagulation and greater tissue damage. A number of newer instruments allow tissue to be grasped between the jaws before applying either bipolar diathermy or ultrasonic energy to seal vessels and achieve haemostasis during dissection, and these are available for both open and minimally invasive surgery. These instruments can save time, but are expensive and must be used with caution to avoid heat transfer and injury to surrounding organs. In situations where no diathermy is available, most vessels clamped in artery forceps should be ligated. However, although the pressure of the artery forceps left on for a minute or two and then released may be sufficient for a small vessel, there is a danger of bleeding restarting later.



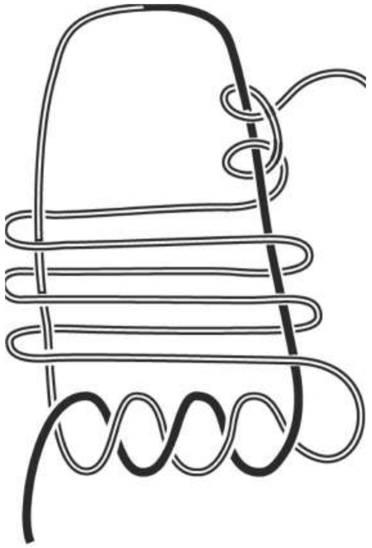
1.7 An alternative transfixion suture, which passes twice through the tissue. ⏎

Laparoscopic knots and sutures

Knots may be tied intracorporeally using laparoscopic instruments or extracorporeally by hand. A locking slip knot such as the Meltzer knot (Figure 1.9) can be tied by the surgeon and the resulting loop introduced through a port with the long end of the ligature remaining on the outside. The loop is passed over the



1.8 (a) A ‘mounted tie’ is used to carry a ligature to the open jaws of artery forceps passed beneath a vessel. (b) After ligation, the procedure is repeated. (c) An isolated section for division is obtained. ⏎

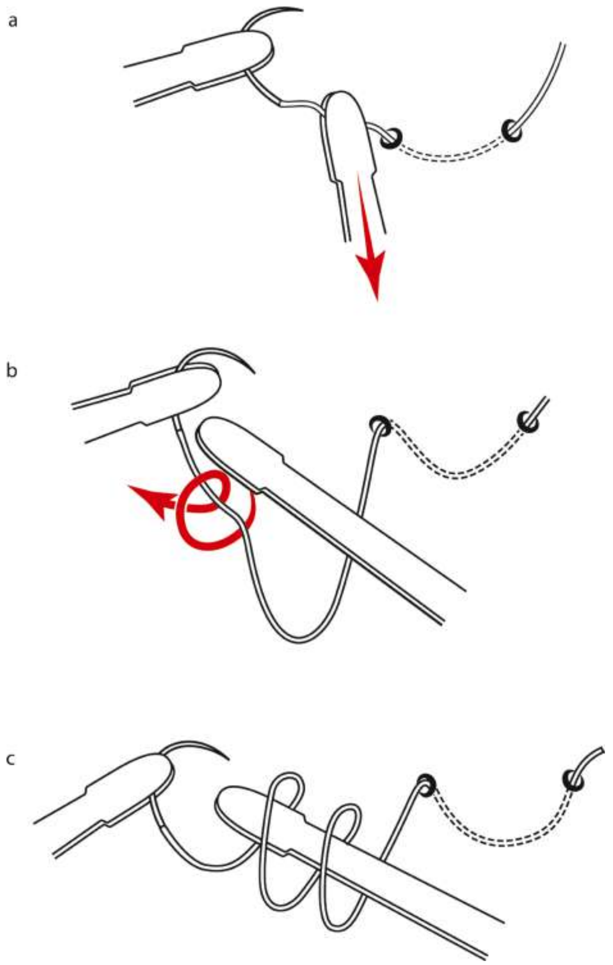


1.9 A Meltzer locking slip knot suitable for braided suture material. ⏎

structure to be ligated and then tightened using a knot pusher. Pre-tied loops such as the Endoloop®, with a disposable inbuilt plastic pusher, are available and may be used instead. A long ligature may be passed through a port, around a structure to be ligated, and back out through the same port. Individual throws of the knot are then tied extracorporeally by hand and tightened using a long laparoscopic knot pusher.

Intracorporeal suturing and knot tying is identical in principle to suturing and knot tying in open surgery, but is more difficult because of the two-dimensional view, the limited space available and the difficulty of making throws with two instruments both approaching the operative field from the same direction. Most laparoscopic graspers do not hold a needle securely enough for accurate suturing, and a pair of laparoscopic needle holders should be used instead. A long suture is difficult to tie within the visual field of the laparoscope, and sutures should be cut down to 10–15 cm. As the direction from which the needle holder approaches the operating site is fixed by the position of the port used, accurate positioning of the needle within the needle holder is necessary for an accurately placed stitch. The needle is most easily positioned for placing a stitch with the right hand by first grasping it loosely near the tip with the left-hand needle holder. If the needle is incorrectly orientated, it can now be adjusted by grasping the suture thread close to the needle with the right-hand needle holder and pushing or pulling, as required. Once the needle is correctly orientated, it can be picked up ready for suturing.

Various methods of tying the knot exist and just one is described here. After placing the stitch with the right hand, the needle is grasped near its tip by the left-hand needle holder and the stitch is pulled through only a short distance. The right-hand instrument then grasps the suture as it exits from the tissue and pulls a loop of suture material towards the camera (Figure 1.10a). The combination of this loop and the curve of the needle makes it easy to wrap two turns of the suture around the right-hand needle holder by rotating it in an arc (Figure 1.10b) prior to grasping the end of the suture material as for a standard instrument tie (Figure 1.10c). The throw is tightened and then the same procedure repeated in reverse for the second throw. When a knot needs tying under tension or slips during tying, a useful technique can be to create an intentional slip knot. Firstly, a standard reef knot with two throws is formed. Then, one end of the suture is grasped both above and below the knot and

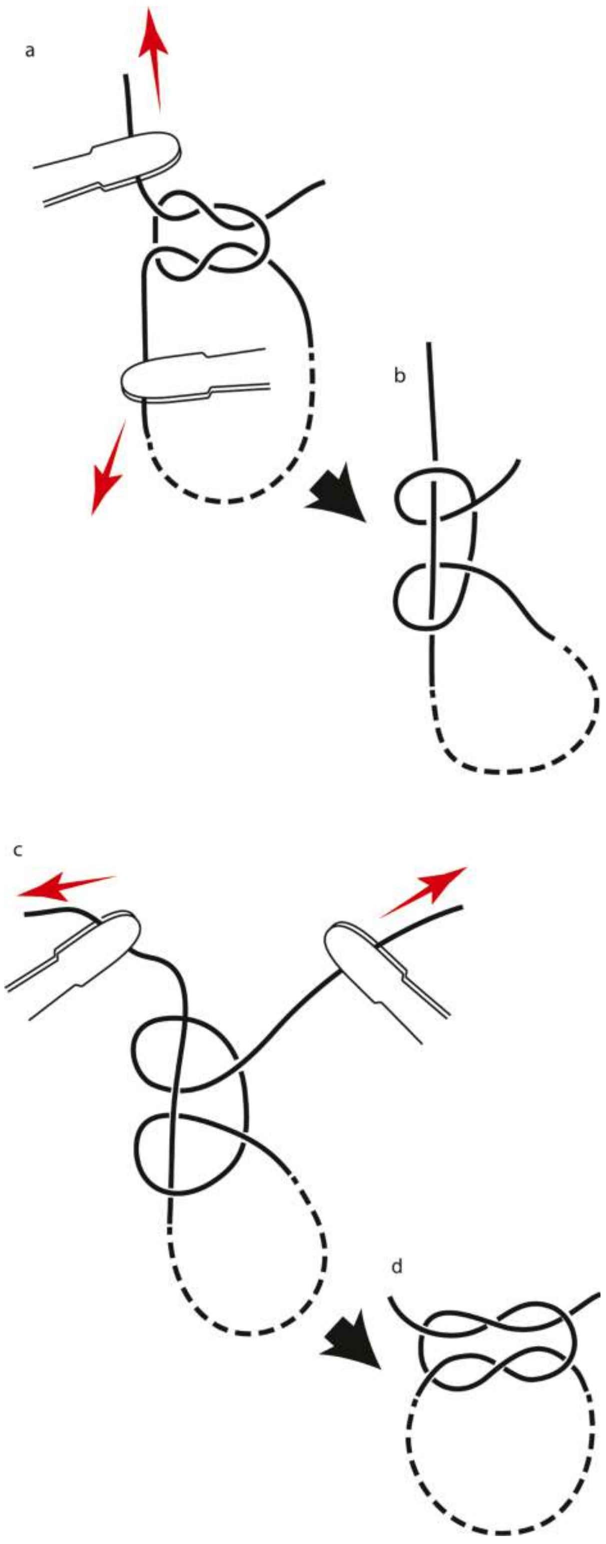


1.10 An intracorporeal suture ligation. (a) The suture is only pulled through sufficiently to allow it to be grasped by the second needle holder close to the needle and pulled to form a loop. (b) The second needle holder is then rotated around the loop as shown by the arrow. (c) Two turns around the needle holder have been achieved and the short end can now be grasped to complete the first throw of the knot. ⏎

pulled taut (Figure 1.11a). The knot will turn into a slip knot with a palpable give and it can then be tightened down as required (Figure 1.11b). Finally, pulling each end of the suture laterally will convert the knot back into a secure, square, reef knot (Figures 1.11c and d), again with a palpable give, to which further throws can be added if required.

DISSECTION

After incision of the skin, almost every operation relies on tissue dissection. This may be to excise a lipoma in the subcutaneous fat or to find the least traumatic access to a long bone by dissecting between muscle bellies. Dissection is needed to mobilise a segment of



1.11 It may be difficult to maintain tension on a knot during a laparoscopic tie. (a) A reef knot has been created but the suture is too loose. Traction in the directions shown will convert it to a slip knot. (b) This slip knot can be tightened. (c) Traction in the directions shown will convert the knot back into a reef knot. (d) A reef knot is created, which is securing a snug suture. ⏎

colon, with its lymphatic drainage intact, or to mobilise intra-abdominal viscera to expose a kidney. In any tissue dissection, natural planes between structures can be found and developed by a blunt or a sharp method of dissection.

In *blunt dissection*, reliance is placed on the assumption that natural cleavage occurs between structures. However, if there is scarring from previous surgery or inflammation, the line of least resistance to separation may instead be through adjacent structures such as major vessels or loops of bowel. Blunt dissection should be used sparingly and with caution. Forceps or scissors, inserted into the plane of dissection, are gently opened, or the surgeon's fingers may be able to feel, and develop, the plane and separate the structures. A pledget swab held in forceps and used to push fat away from an underlying vessel or duct is another form of blunt dissection.

In *sharp dissection*, the surgeon is following a plane under direct vision. Identification of the plane may be by a change in colour or size of fat lobules at the edge of an organ or on the surface of a cyst or a lipoma. Dissection may also be in an areolar plane, which opens when the tissue is held on stretch. These areolar planes are between adjacent structures of different embryological origin. Only fine bands of tissue, almost avascular, cross these planes. These bands are divided under direct vision with a scalpel, scissors, diathermy or another energy device. It is always important to divide the most stretched band, which then allows distraction to show the next band to be released. Therefore, dissection should not be continued exclusively in one area but should move backwards and forwards along the plane. An increase in bleeding is nearly always a sign that dissection has strayed out of the correct plane or that the underlying pathology, whether inflammatory or malignant, has breached the plane.

REDUCTION OF BLEEDING

Blood obscures the view for the surgeon, and all surgery is easier if bleeding can be reduced. This is particularly true in minimally invasive surgery, where blood cannot be mopped up as effectively, and blood absorbs light, leading to a poorer view and more difficulty in identifying planes of dissection. In addition, blood loss increases morbidity. Tourniquets, or vascular clamps, can give the surgeon an almost bloodless operative field in some circumstances, and even temporary finger pressure on an artery proximal to an injury can be a useful manoeuvre in an emergency. Bleeding from small vessels can be reduced by infiltration of adrenaline containing local anaesthetic or saline solution. Venous ooze can be particularly troublesome if there is venous engorgement, and positioning of the patient on the operating table can reduce this significantly. The head-down tilt (Trendelenburg) position for varicose vein and pelvic surgery and the head-up tilt for thyroid surgery are examples. However, the rare, but potentially lethal, complication of air embolus must be remembered. More sophisticated methods for reducing central venous pressure for liver surgery are discussed in Chapter 12. The haemodynamic conditions should be returned to normal, if possible, before completion of the operation to reveal previously unidentified bleeding points.

INTRAOPERATIVE DECISIONS

Even standard operations are never identical, and each minor adaptation involves a decision by the surgeon. These routine decisions over access, degree of mobilisation, viability of tissue or the tension in an anastomosis, or wound closure, can be likened to the decisions a driver has to make regarding speed or overtaking on any journey; the route may be the same but traffic and weather conditions vary. More major decisions can relate to variations in vascular anatomy, unexpected pathology or complications during surgery. Exploration of an apparently simple infected area may reveal extensive dead tissue, or an intended appendicectomy can uncover other pathology. A vascular reconstruction may have to be modified when a donor or recipient artery proves unsuitable. A malignancy may be more advanced than anticipated, and the choice between very radical surgery or palliative surgery is not always straightforward. A gastric conduit may necrose and an alternative reconstruction may have to be considered. When involved in major operations, the surgeon must always consider their 'get-out strategy' – how to reconstruct a functional gastrointestinal tract if the next phase of the dissection shows tumour resection to be impossible, or how to restore distal perfusion if vessels prove unsuitable for bypass grafts. The way in which these intraoperative decisions are taken can only really be learnt through long periods of operating and assisting in the operating theatre. However, throughout this book, these issues have been addressed in the relevant sections.

SALVAGE SURGERY

This implies an often temporary solution to a challenging situation, whether caused by trauma, a disease process or a complication of previous surgery. The operation is designed to secure the survival of the patient, and definitive surgical reconstruction is delayed. There is an old surgical adage: 'It is better to have a live problem than a dead certainty.' Salvage surgery embraces this concept.

Control of haemorrhage

Arterial trauma can normally be repaired or reconstructed at the initial exploration. However, a surgeon with limited vascular experience or working in a conflict zone might have to opt for a temporary solution. For example, a torn femoral artery can be ligated in the groin to save a patient's life during transfer to specialist facilities. Limb viability may be maintained on collaterals or by a vascular shunt until a reconstruction can be undertaken in more appropriate circumstances. Packing a bleeding liver or ligating the internal iliac vessels for severe pelvic haemorrhage are other salvage manoeuvres. Postoperative haemorrhage within a few hours of an operation is usually relatively straightforward to deal with at re-exploration – a haematoma is evacuated, a vessel that is actively bleeding is secured and the area is drained. Secondary haemorrhage, around 10–14 days postoperatively, is associated with infection. The control of individual vessels in friable tissue is seldom possible, and a salvage procedure with packing is more appropriate. Within the abdomen, interventional radiology and embolisation of feeding vessels should be considered as an alternative to surgery. A secondary haemorrhage from a disrupted infected arterial graft anastomosis poses dual salvage challenges: the control of haemorrhage and the restoration of distal perfusion.

Excision of necrotic tissue and infected prostheses

Pus and infected collections must be drained, whether surgically or radiologically. When pus is associated with an infected prosthesis, drainage and antibiotics are seldom sufficient. Initial resolution is normally followed by further infective episodes until the prosthesis is removed. Although this seldom has to be undertaken in an emergency, the initial surgery is often again a salvage procedure. The first operation is to remove the infected artificial joint or mesh and the second, some months later when all infection has been eradicated, is to perform a further arthroplasty or repair the recurrent hernia.

Necrotic tissue must be excised, and delay only results in further deterioration of the patient. (The only common exception to this general surgical rule is pancreatic necrosis.) A gangrenous limb can be amputated and a strangulated loop of bowel resected as a definitive procedure. The extensive soft tissue necroses seen in necrotising fasciitis, and in a mesenteric vascular incident, may require one or more salvage procedures to excise dead tissue, as further necrosis may occur after the initial exploration. In mesenteric ischaemia, it is often preferable to excise the bowel that is clearly gangrenous and leave the bowel ends stapled off with a planned relook operation after 24–48 hours. A bowel that was of questionable viability at the first operation may have either recovered after resuscitation and stabilisation of the patient or become frankly ischaemic and require further resection. Reconstruction can be deferred to a later operation. Similar considerations occur when, for example, the left colon becomes ischaemic after aortic aneurysm surgery or an oesophageal conduit becomes unviable. The initial salvage operation is excision of the necrotic tissue with establishment of a colostomy for ischaemic left colon or of a temporary cervical oesophagostomy and feeding gastrostomy for an ischaemic oesophageal conduit. The restorative colorectal anastomosis, or the construction of an alternative oesophageal conduit, is undertaken some months later.

Leakage from the gastrointestinal tract

In many trauma situations, a single definitive operation will suffice. However, in patients with major or massive trauma, the patient may be too compromised to survive the lengthy operation required. The only initial concern is to arrest haemorrhage, clear intestinal contents from the peritoneal cavity and prevent further leakage. This salvage surgery is described as 'damage control' (see Chapter 17).

Anastomotic leaks most commonly occur around 5–6 days postoperatively. Simple repair is generally not an option, as there is surrounding infection with friable and sometimes poorly perfused tissue. Salvage relies on diversion of intestinal contents from the anastomosis, if this is possible, and surgery to restore gastrointestinal continuity is usually delayed for 6 months. Faeces can be diverted from colonic and rectal anastomoses with either a colostomy formed from the proximal end of the anastomosis or an upstream ileostomy or colostomy. If diverting upstream, a washout of the distal bowel is recommended. Upper gastrointestinal anastomoses can be less easily excluded, but leakage can be reduced by stopping oral intake and reducing secretions with octreotide. Drainage of intestinal contents may be profuse and prolonged, and either enteral feeding, distal to the leak, or parenteral feeding must be instigated.

Following major intra-abdominal catastrophes, it may not be possible to close the abdominal wall owing to increased intra-abdominal pressure and fistulae. The salvage procedure of temporary abdominal containment, including leaving an abdomen open by laparostomy, is discussed in Chapter 6.

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2

Surgical instruments and technology

Amy Lord and Rohin Mittal

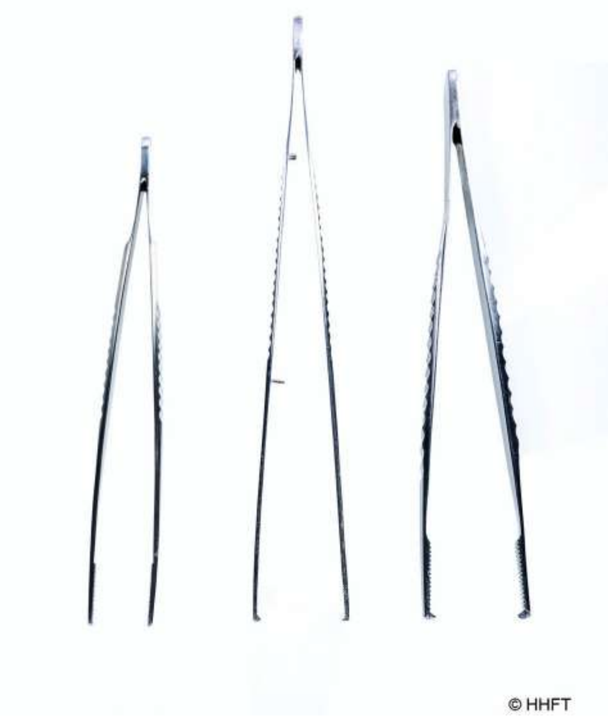
BASIC SURGICAL EQUIPMENT

It is beyond the scope of this chapter to list and describe all surgical instruments. Different surgical disciplines use a multitude of specialised instruments, and the eponymous names for many of these instruments differ by hospital, region and country. Further detail about the equipment used outside the main general surgical disciplines is given in subsequent chapters. This chapter gives a very basic overview of some of the equipment that may be found in a major general surgical set or that may be needed for general open emergency surgery, such as emergency laparotomy or hernia repair. Surgical instruments can be broadly categorised into instruments used to grasp, cut or retract tissues.

GRASPING INSTRUMENTS

Instruments used to grasp tissues can be divided into non-ratcheted and ratcheted instruments. Non-ratcheted dissecting forceps are used to accurately pick up tissue during dissection. They may be atraumatic (e.g. DeBakey forceps) or have teeth that cause some trauma but allow a better grasp of the tissue. Different applications require different types of forceps and there are many options. Examples include fine-toothed forceps for grasping the skin when carrying out subcuticular skin closure, heavy-toothed forceps for grasping the sheath when closing a laparotomy and fine non-toothed forceps for gently handling the bowel or picking up a bleeding vessel to allow coagulation with diathermy (Figure 2.1).

Ratcheted graspers may also be traumatic (e.g. Littlewood and Lane forceps) or atraumatic (e.g. Babcock forceps) and are often used to allow an assistant to lift tissues and provide tension for dissection (Figure 2.2). Artery forceps are some of the most commonly used ratcheted graspers and are used when ligating blood vessels. They come in different sizes, with size selected according to the size of the vessel, ranging from very fine artery forceps (e.g. mosquito forceps) to heavy forceps (e.g. Roberts forceps). These examples can be seen in Figure 2.3. Atraumatic vascular clamps allow occlusion of a vessel that is not going to be ligated and will be discussed in more detail in the vascular surgery chapters. Other non-tissue-grasping instruments include needle holders for suturing and towel clips used to secure surgical drapes and instruments.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2.1 A selection of commonly used forceps. From left to right: DeBakey (atraumatic), Gillies (fine-toothed) and Lane (heavy-toothed) forceps. ⏎

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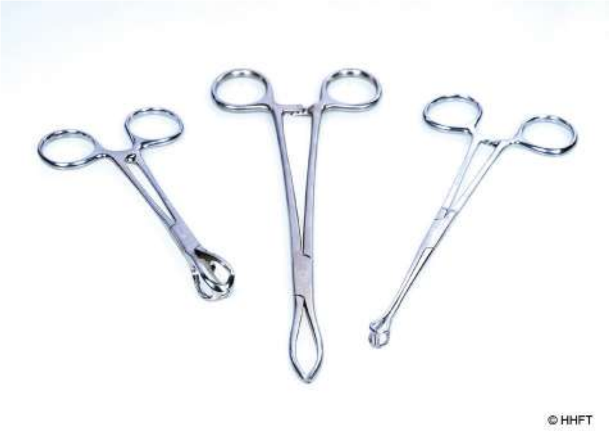
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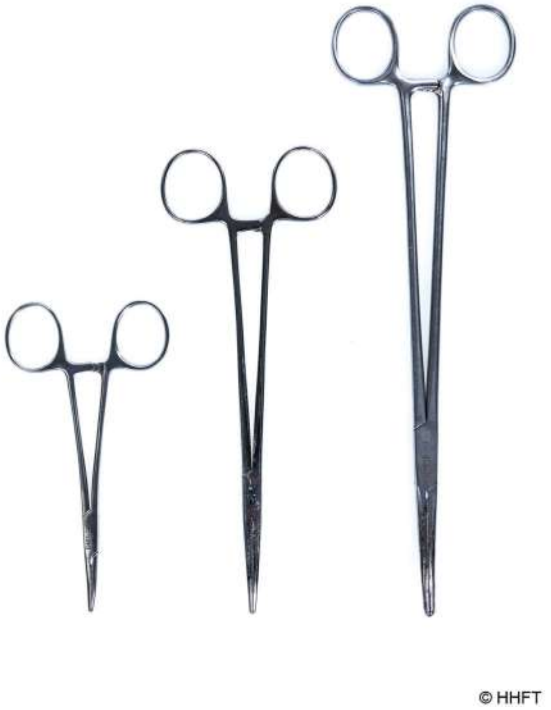
2.2 A selection of ratcheted graspers. From left to right: Lane, Littlewood and Babcock forceps. ⏎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2.3 Commonly used artery forceps. From left to right: mosquito, Fraser–Kelly and Roberts forceps. ⏎

CUTTING AND DISSECTING INSTRUMENTS

Cutting instruments can broadly be divided into scalpels and scissors. Various shapes of scalpel blades are available and are illustrated in Figure 2.4. The most commonly used are a 10 blade for large incisions (e.g. when opening the skin for a laparotomy), an 11 blade for small stab incisions (e.g. for laparoscopic port insertion) and a 15 blade (e.g. for fine incisions such as the excision of skin lesions). Scissors may be used for tissue dissection or cutting sutures and can be fine scissors (e.g. McIndoe or Metzenbaum scissors) or heavy scissors (e.g. Mayo scissors). They may also come in curved or straight variations, depending on their application, and different lengths depending on the depth of the operating field.

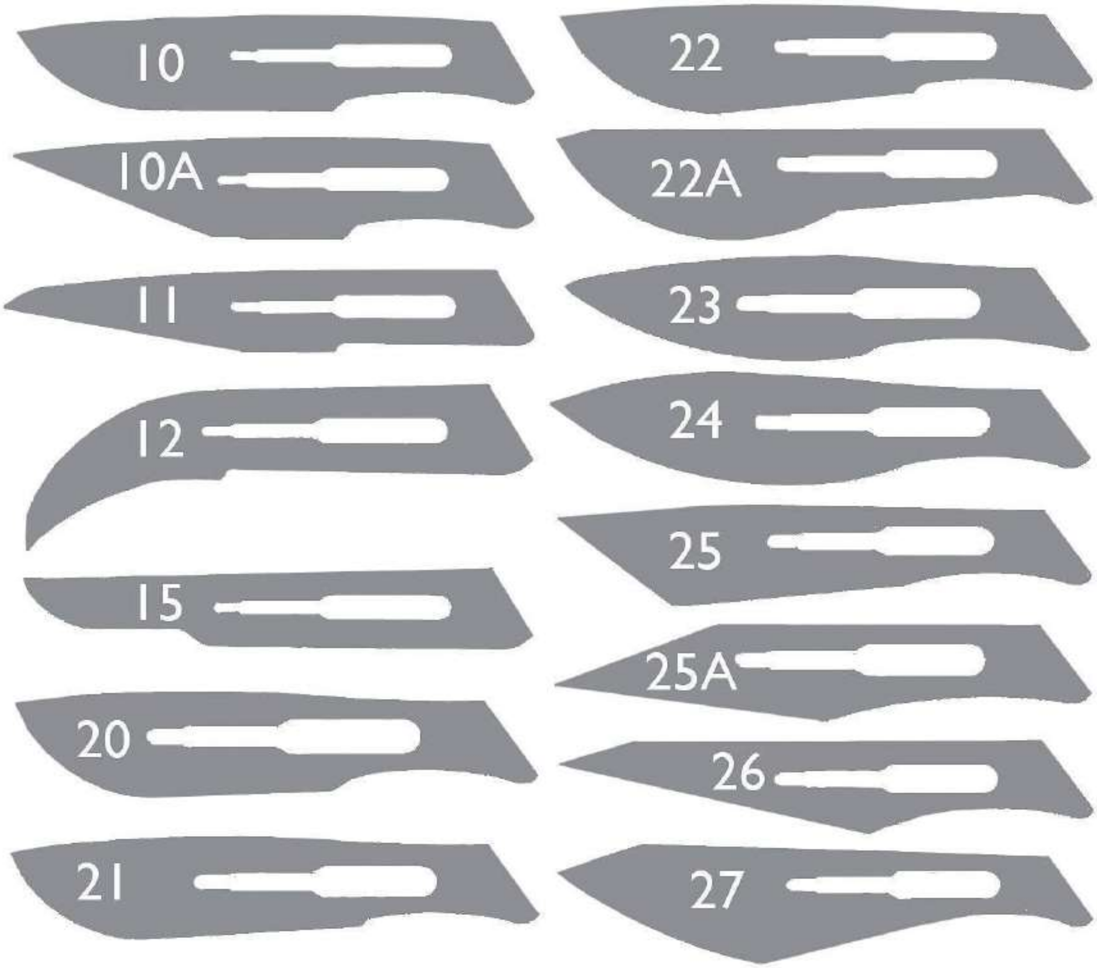
RETRACTORS

Exposure of the operative field is key during all surgery and, therefore, retraction of tissues is extremely important. A multitude of handheld retractors are available and come in a number of shapes and sizes, appropriate to their different applications. Different lengths and widths are needed depending on the size of the incision and the depth of the tissue being retracted. Some come with a lip, which allows more accurate tension to be placed on the tissue being retracted (e.g. a St Mark's retractor for use in the pelvis when carrying out rectal cancer surgery); others are smooth (e.g. the Kelly and Deaver retractors) for atraumatic retraction of organs such as the liver. The advantage of handheld retractors is that they can be used dynamically by the assistant and constantly adjusted to allow tissues to be kept under tension. The disadvantage of handheld retractors is that, in long cases, it can be tiring for the assistant, and they also mean that the assistant no longer has both hands free to assist with the rest of the operation.

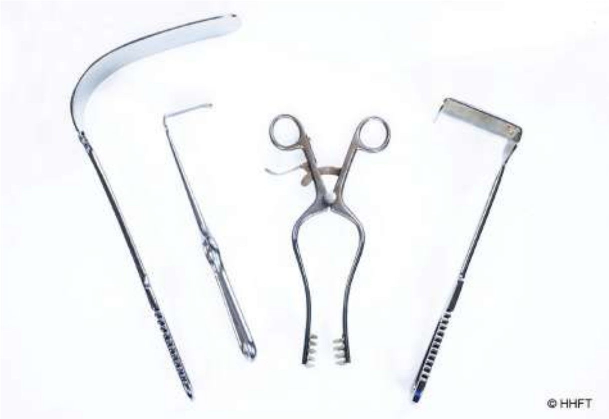
Therefore, self-retaining retractors are often used when retraction is needed for longer periods. These also vary from small scissor-shaped retractors (e.g. the Travers retractor) to large retractors suitable for retracting the abdominal wall during a laparotomy. An increasingly popular option for retraction of varying sizes of wound is a circular wound protector/retractor such as an Alexis retractor, which consists of dual flexible rings, connected by a plastic film, which are placed inside and outside the wound, providing circumferential retraction. These come in smaller versions, which can be used for laparoscopic specimen extraction, and have a cap that allows re-establishment of the pneumoperitoneum and re-insertion of a port through the cap. Alexis retractors also come in larger versions, which can be used for a laparotomy. They have been shown to reduce surgical site infection, which is an added advantage. Large table-mounted retractors, such as an Omni-Tract®, provide excellent exposure and are therefore useful for major complex operations in which large incisions are needed. A selection of retractors is shown in Figure 2.5.

SUTURES

Closure of a skin wound is often the first surgical procedure that a trainee undertakes, and the choice of



2.4 Examples of the different shapes of scalpel blades available. ⏎



2.5 A selection of retractors. From left to right: Kelly, Langenbeck, Travers and Morris retractors. ⏎

suture material and method for skin surgery is covered in more detail in Chapters 4A and 4B. However, sutures are also used for gastrointestinal, urological and vascular anastomoses, for abdominal wall closure and for the repair of tendons and nerves. In general, sutures are designed to hold healthy tissue in apposition to allow healing, and tissue support by the sutures is required until the tensile strength in the wound, or anastomosis, is adequate to prevent disruption. Too tight a suture should be avoided, as it merely cuts through the tissue or causes ischaemia. When judging tension, it should be remembered that all sutures become tighter after 24–48 hours as the traumatised tissue swells. An additional difficulty is the tendency for the whole suture to tighten as the knot is tightened.

Suture material, whether monofilament or braided, may be bioabsorbable or alternatively can remain in the tissue indefinitely unless removed. Monofilament material is less traumatic to tissues, but a braided suture is easier to handle, with more secure knots. Non-absorbable sutures are needed for vascular anastomoses but should not be be used for suturing the biliary or urinary tract, where they have been shown

Table 2.1 Suture materials ⏎

Type	Form	Material
Non-absorbable	Braided	Silk Ethibond™ (polyester)
	Monofilament	Nylon Prolene™, Surgipro™ (polyester) Stainless steel wire
Strength lost within 2 weeks	Braided	Vicryl Rapide®, Dexon™ (polyglycolic acid)
	Monofilament	Plain catgut Caprosyn™, Monocryl®
Strength lost between 2 and 4 weeks	Braided	Vicryl™, Polysorb™ (polyglycolic acid)
	Monofilament	Chromic catgut
Strength lost between 4 and 6 weeks	Monofilament	Polydioxanone sodium (PDS), Maxon™

to cause stone formation. Chronic abscesses can also form around non-absorbable sutures, particularly if braided. Bioabsorbable sutures lose strength at different rates and are all associated with a tissue reaction as the material is degraded and absorbed.

Therefore, the choice of suture material is sometimes crucial, although more often it is mainly a matter of surgeon preference, cost or availability. Sutures made from different materials may have similar properties. Conversely, sutures of similar materials may exhibit different behaviours, reflecting the manner in which they have been manufactured. This has resulted in the increased use of trade names. The properties of some sutures, in particular those to which later references are made, are summarised in Table 2.1.

MORE SOPHISTICATED SURGICAL TOOLS

The techniques discussed in the following sections are in standard use in operating theatres in the UK and other high-income countries. In many instances, the advantages over the basic method are marginal and related mainly to speed but, in other instances, they make a difficult manoeuvre easier and safer. The disadvantage is one of cost, and many surgeons who are working in countries with major healthcare budget restrictions will find these alternatives unaffordable.

LIGATURE AND SUTURE ALTERNATIVES

There is increasing use of clips and staples for securing vessels, and these devices have proved invaluable both in minimal-access surgery and in situations where access is difficult. Small linear cutting stapling devices have been of particular benefit in the safe division of large veins, where the length of the vein is too short to accommodate ligatures. The right renal vein and the hepatic veins are examples. It is a faster and more secure technique than that of oversewing the vein. The angled head of these stapling devices allows access into restricted surgical fields. Other developments have been in vessel-sealing technologies. LigaSure™ and Ultracision® are electrothermal bipolar tissue-sealing devices; Harmonic® coagulating shears use high-frequency mechanical vibrations in the ultrasonic range to fragment tissues and seal small vessels. These have proved useful devices for dividing the mesentery of the bowel in both open and laparoscopic surgery.

Simple skin clips have long been an alternative to sutures for apposing skin, but more sophisticated devices were required before there was an alternative to sutures for anastomosing the bowel or suturing a vein. The linear and circular stapling devices used in abdominal surgery are described in more detail in Chapter 7. Whereas the contribution of the linear staplers has been mainly that of speed, the circular staplers have greatly simplified some oesophageal, and low rectal, anastomoses, where access makes a sutured anastomosis very difficult.

MORE SOPHISTICATED DISSECTION TECHNIQUES

Electrosurgical dissection

Initially, diathermy was used almost exclusively to coagulate tissue and was thus a faster way to deal with small blood vessels. Increasing technical sophistication has allowed a range of diathermy settings to include various blends of coagulation and cutting modes. Sharp dissection is now increasingly performed with monopolar diathermy. It has the advantage that it prevents multiple small bleeding points in areolar planes and can give the surgeon an almost bloodless field as dissection proceeds. Larger vessels still require individual attention. It is important that dissection is combined with retraction to open the tissue planes and keep any fine structure to be divided on stretch. Diathermy of tissue that is not on tension produces charring and can fuse tissues and obscure the plane of dissection. Skin incisions can be made with diathermy in cutting mode, which almost eliminates the small bleeding points in the dermis, with no adverse effects in terms of cosmesis, healing or infection rates. Similarly, if the bowel is divided with diathermy, submucosal bleeding is significantly reduced. However, diathermy dissection is not without risk. The general risks of diathermy are discussed in Chapter 3 but there are also local risks. The surgeon is more likely to stray from the correct plane of dissection, and often more damage is caused before the mistake is realised. Inadvertent diathermy injury, when dissecting close to the bowel, may result in unrecognised thermal injury, which can lead to delayed perforation. There is also concern over thermal damage to adjacent nerves such as the autonomic plexi during pelvic dissection and the recurrent laryngeal and facial nerve in neck surgery.

Ultrasonic dissection

An *ultrasonic scalpel* can also be used as an alternative to a diathermy hook in laparoscopic dissection. Although the ultrasonic Harmonic scalpel generates heat, the zone of thermal energy produced is less than with monopolar, or even bipolar, electrocautery. Additionally, less smoke and steam are generated, both of which can impair visibility during a laparoscopic procedure.

The *Cavitron ultrasonic surgical aspirator* has generally replaced finger fracture of liver tissue for dissection through the liver. This device disrupts liver parenchyma, exposing small vessels that are then secured. More detail is given in Chapter 12.

Laser tissue destruction

A laser beam can pass harmlessly through superficial tissue to destroy the deeper tissue on which it has been focused. Lasers are not used extensively in general surgery but have an increasing role in ophthalmology and prostatic surgery.

MINIMAL-ACCESS SURGERY

LAPAROSCOPY, THORACOSCOPY, ARTHROSCOPY AND THE CREATION OF ARTIFICIAL SPACES

The peritoneal, pleural and joint cavities are ideal, delineated potential spaces that can be inflated for video-assisted minimal-access surgery. Artificial spaces can also be created within loose areolar tissue, and an increasing number of operations can be undertaken by this minimal-access approach.

Laparoscopic access, and some general intra-abdominal principles, are discussed in Chapter 6. In all chapters, the minimal-access operations in general use are described. However, in all video-assisted surgical procedures, there are similar challenges for which specific surgical techniques have been developed.

TRANSANAL ENDOSCOPIC MICROSURGERY

Transanal surgery can now be carried out using a variety of platforms, such as transanal endoscopic microsurgery (TEMS) or transanal minimally invasive surgery (TAMIS). TEMS or TAMIS can be used for large villous adenomas, but are also increasingly being used for early rectal cancers as part of an organ preservation approach. Excellent views and small instruments designed to pass through the working ports allow very precise surgery up to approximately 15 cm from the anal verge. The technique and its place in the surgery of rectal cancer are discussed in more detail in Chapters 14 and 15.

LAPAROSCOPIC SURGICAL PROCEDURES

Similar challenges are encountered in all minimal-access operations. The basic principles of surgery, including tasks such as retraction, dissection and haemostasis, and the intended end result are the same as in open surgery. However, the techniques used to achieve these tasks differ and are described for laparoscopic surgery in the following sections. The surgeon's hands are not in the operative field, and long-shafted instruments have to be manipulated from outside the body. Changing from one instrument to another is more time consuming than in open surgery. Some manoeuvres are easier laparoscopically, but other very basic open skills, such as suturing, are more challenging. Manual palpation is no longer an option, and the operator has to rely on vision with some degree of feedback on tissue through the instruments. However, views are excellent once the surgeon has adjusted to the two-dimensional video picture and the inevitable distortions of size.

Visualisation

Good-quality laparoscopic visualisation is dependent on the laparoscope, the camera and the display stack. The choice of camera, and stack, is largely limited by cost and available equipment, but laparoscope sizes ranging from 3 to 10 mm are available and the viewing angle varies from 0 to 45°. Smaller laparoscopes, and those with a more angled view, generally provide less light and inferior views. The advantage of an angulated scope, when manipulated by a skilled assistant, is the ability to look around structures that might otherwise be in the line of sight or to look at the operative field from different directions through the same port.

A poor laparoscopic view may be caused by a number of factors. The gas within the operating cavity will be at high humidity and body temperature. If a cold scope is introduced into the cavity, condensation will form on the lens, thus obscuring the view. This can be prevented by warming the scope or using anti-misting solutions. Repeated or prolonged removal of the scope from the patient will allow it to cool down and should be avoided. Diathermy and ultrasonic dissection produce smoke and cellular debris, which obscure the view, and these can be cleared by allowing a constant controlled escape of gas through one of the ports. Meticulous haemostasis is also important, as not only does blood obscure the tissue planes, but also blood is poor at reflecting light, and significant volumes of blood within the operating cavity result in low light levels and poor views.

Dissection

Sharp dissection in laparoscopic surgery may be carried out using scissors, diathermy or ultrasonic dissection. The entire non-insulated part of an instrument used for diathermy must be visible prior to applying diathermy current to prevent injury to structures outside the field of view. It must also be remembered that the ultrasonic dissector retains heat and may cause a thermal injury even after the power has been released.

Blunt dissection under direct vision is used extensively during laparoscopic surgery. The plane of dissection should first be recognised, and tissues should then be put under tension by retraction from the assistant and the non-operating hand of the surgeon. Tissue on either side of the plane may then be pulled away from it, using either the same instrument as used for sharp dissection or a laparoscopic pledget.

Haemostasis

Tying a ligature is much more difficult laparoscopically (the basic techniques are described in Chapter 1) and other techniques are usually used for haemostasis. Small vessels may be divided and sealed by an ultrasonic dissector or diathermy. Although these energy devices may officially state that they can safely seal vessels up to 7 mm in diameter, many surgeons prefer not to rely on them for major named vessels and instead use laparoscopic clips or vascular stapling devices to ligate the vessels securely, under vision, after they have been dissected out and isolated. Various laparoscopic clip applicators are available and range from pre-loaded metal clips (e.g. the Ligaclip™) to larger polymeric locking clips (e.g. the Hem-o-lok® system). Vascular cartridges with a smaller staple height than those used for stapling the bowel can be used to divide vessels and are preferred by some surgeons.

Where a vessel is divided inadvertently or if a clip or stapler fails, prompt control of the resulting haemorrhage is needed to maintain a good view of the operative field, and it is important that any instruments required are available quickly. If a bleeding vessel can be seen and grasped safely, then it can be controlled by any of the above techniques. Otherwise, haemostasis can normally be achieved temporarily by applying direct pressure using a small tonsil swab, which can be inserted through a laparoscopic port, or with a laparoscopic pledget. With bleeding controlled temporarily, it may prove possible to gain access to the bleeding vessel safely and complete haemostasis. If it is not possible to control bleeding without risking damage to adjacent structures, it may be necessary to convert to an open operation.

ROBOTIC SURGERY

Robotic surgical platforms have been available for over two decades, but numerous issues – such as the initial cost outlay for the robot, the cost of consumables, theatre space requirements, training needs and a lack of evidence of clinical benefit – has meant that their use is still not widespread, especially in lower income countries. The development of cheaper platforms over recent years and greater experience amongst early adopters means that robotic-assisted surgery is becoming increasingly commonplace.

The term robotic surgery is somewhat confusing and often leads patients to believe that their operation is being carried out by a machine, without input from a surgeon. The reality is that robots are just a more sophisticated form of minimally invasive surgery. The surgeon is still in full control, but has the benefit of instruments that can be manipulated remotely, and more accurately, than the ‘straight sticks’ used in laparoscopic surgery. Robotic instruments range from various graspers to scissors, energy devices, clipping devices and staplers. Their advantage over their equivalent laparoscopic instruments is that they all have a ‘wrist’ joint that can be manipulated to allow more control, particularly in narrow, tight spaces. Robotic platforms also allow the camera to be controlled by the surgeon, rather than relying on an assistant, meaning that there is more control and less unintentional camera movement. Three-dimensional vision is also possible, through the use of either a binocular console or three-dimensional glasses, which is a particular advantage for procedures involving suturing and knot tying.

There are several downsides of robotic-assisted surgery, including the lack of tactile feedback, which can cause inadvertent trauma to tissues. Being unscrubbed and away from the operating table is often more comfortable for the surgeon, but may present challenges in an emergency (e.g. sudden bleeding, which requires rapid conversion to an open operation). The surgeon must rely on their operating tableside assistant, who increasingly may not be a surgeon, to safely insert ports, insert and remove instruments, and deal with any problems with the robot during the operation, while the surgeon is remote from the patient at the robotic console.

MINIMAL-ACCESS INTERVENTIONAL PROCEDURES

The minimal-access techniques for gastrointestinal and vascular procedures are of particular interest to the general surgeon, but there has been a parallel development in other surgical disciplines. This area of surgery has expanded enormously in the last 40 years in those countries that can afford the expensive equipment and its skilled maintenance. Surgeons are no longer the only interventionalists, and cooperation in a multidisciplinary setting has become more important. Close collaboration between surgeons and other interventional specialties is very important – radiological or endoscopic procedures may be preferable to surgery in many cases, but surgeons may need to be involved with dealing with failed procedures and complications when these occur.

When two options are considered – a traditional open operation or a minimal-access procedure – it is important to consider not only whether an operation can be done by a less invasive technique, but also whether it is associated with better or worse patient outcomes. This decision is related to patient and disease factors, but the relative skill of the operator in each method is also of great importance.

Patients are usually delighted that they can be saved a ‘major operation’. A short hospital stay is anticipated, along with a fast recovery with either no external wound or only small port site wounds. Unfortunately, this leads many to believe that the procedure itself, and the inherent risks, are minor compared with traditional open surgery. In many cases, although the access is minimal, the surgery itself is still major. Preoperative discussions are important, otherwise the scene is set for blame, and even litigation, if complications arise.

Interventional radiology

Interventional radiology plays an increasing role in the management of the surgical patient. In many scenarios, a minimal-access technique, under image-guided control, has the potential to replace a major surgical intervention. One example is the use of cross-sectional imaging, such as computed tomography (CT), ultrasound or magnetic resonance imaging, to demonstrate the presence and position of fluid collections such as pus. Adjacent vital structures are also delineated and a drain can safely be inserted under image control. Nephrostomy drainage of an obstructed kidney is now routinely established using a similar technique. Lumbar sympathectomy is now a radiological rather than a surgical procedure. The sympathetic chain is ablated by a chemical paravertebral injection under image-guided control.

Angiography as a diagnostic tool has been developed into various therapeutic interventions. Fibrinolysis and angioplasties, with or without stents, have saved many patients from major vascular operations, and endovascular aneurysm repair is an increasingly utilised option, particularly in patients who may be less fit for open surgery (see Chapters 18 and 19). Selective arterial embolisation is another radiological intervention with great potential for the surgeon. Preoperative embolisation can be used to reduce the vascularity of a renal tumour. More often, it is used as an alternative to surgery to obliterate feeding arteries and arrest haemorrhage. In the gastrointestinal tract, radiological embolisation has proved particularly valuable in angiodysplastic colonic bleeding and in secondary haemorrhage after radical gastrectomy. Embolisation may also play a major role in the control of haemorrhage from major trauma. In fact, embolisation can commonly replace emergency splenectomy or surgery for a traumatised liver after blunt abdominal trauma in centres where there is good access to timely CT imaging and interventional radiology. It can also play an important role in controlling bleeding from a fractured pelvis. Venography allows the insertion of venous stents, inferior vena caval filters for the reduction of pulmonary emboli and testicular vein embolisation to treat varicoceles. Endovascular transhepatic insertion of a portosystemic shunt (TIPSS) has virtually replaced any open portosystemic shunt for portal hypertension in centres where this technology is available. All these options are discussed in the relevant chapters. Cardiac angiography, including angioplasty and stents, is traditionally undertaken by cardiologists rather than radiologists. Ablation of abnormal electrical foci in the myocardium, closure of septal defects and even some valve surgery is increasingly being undertaken by this route.

Interventional gastroenterology

Interventional gastroenterology has also expanded in recent years. Originally, the endoscopist looked directly down the endoscope but now the camera on the endoscope allows the procedure to be visualised by watching the video image on a screen. Oesophageal varices are routinely treated endoscopically by sclerosant, or banding techniques, and the first-line treatment of bleeding gastric or duodenal ulcers is by adrenaline or sclerosant injection, endoscopic clips or laser photocoagulation. Endoscopic retrograde cholangiopancreatography is usually combined with a therapeutic manoeuvre, such as the placement of a stent in biliary obstruction, or with sphincterotomy and extraction of stones from the biliary tree. Endoscopy can be employed to allow the drainage of a pancreatic pseudocyst into the stomach. Colonic polyps are routinely removed at colonoscopy. The ability to raise a gastrointestinal polyp off the muscle coat by submucosal injection of a dilute solution of adrenaline has expanded the technique so that larger, flatter polyps in the thinner-walled right colon can also be removed by experienced interventional endoscopists. In lesions that are thought to be benign, an endoscopic mucosal resection technique using an endoscopic snare is generally utilised; however, in early cancerous lesions, deeper resection in the submucosal plane is also possible using an endoscopic submucosal dissection technique to excise the lesion *en bloc* with a deeper margin. This utilises an endoscopic knife and requires more advanced endoscopic skill. A similar manoeuvre is employed for endoscopic resection of early gastric and oesophageal cancers.

Oesophageal, pyloric and colonic obstructions were once managed exclusively by surgeons. In all of these pathologies, an endoluminal stent can be placed in many patients across the obstruction, either as a definitive palliative treatment or as a bridge to surgery, with or without neoadjuvant oncological therapy. These stents can significantly reduce the need for palliative surgery in a patient with advanced malignancy.

3 Perioperative care

Rohin Mittal and Amy Lord

The perioperative period refers to the time frame surrounding any surgical procedure. It comprises three distinct phases: preoperative preparation, the intraoperative phase and postoperative recovery. The primary aim of the perioperative period is to create optimal conditions for the patient before, during and after surgery for successful recovery. Effective management of patients through each of these three phases is crucial for good surgical outcomes. The perioperative period involves optimising health status, managing potential complications and ensuring a smooth recovery process. This chapter will delve into each of these three phases of perioperative care.

PREOPERATIVE CARE

Preoperative care is crucial and is generally the responsibility of the surgeon. The preoperative period should be utilised for relevant investigations and preparation for surgery. This preparation may pertain to the surgery itself (e.g. controlling thyrotoxicosis before thyroidectomy) but must also encompass the optimisation of the patient's overall condition and the management of coexisting medical pathology. It allows time for implementing prehabilitation protocols along with components of the Enhanced Recovery After Surgery (ERAS®) guidelines.

TIME AVAILABLE FOR PREOPERATIVE OPTIMISATION

The time available for general preoperative preparation of a patient is highly variable and dependent on the rate of deterioration in the underlying surgical condition. The surgeon may have anywhere from a few minutes to many months in which to make improvements.

The 4-minute window

This is the situation when the patient's only chance of survival is with immediate surgery. Examples include exsanguinating haemorrhage and cardiothoracic trauma, where the mechanics of gas exchange and cardiac output have been disrupted. Surgery must proceed alongside general resuscitation and forms an integral part of it. This salvage surgery is discussed further in the appropriate specialty chapters.

The 4-hour window

Many gastrointestinal surgical emergencies are included in this category. Patients are often fluid- and electrolyte-depleted and, although preoperative resuscitation is important, the underlying pathology is advancing. The timing of surgery is important, and full use must be made of this preoperative window in the light of haematological and biochemical values, emergency imaging and electrocardiogram (ECG) findings. The general principles in these situations are fluid and electrolyte management, cardiorespiratory optimisation, correction of clotting and endocrine abnormalities, and management of sepsis with antibiotics.

Fluid and electrolyte replacement The initial loss of fluid and electrolytes is from the intravascular compartment. Equilibration occurs rapidly within the whole extracellular compartment, and interstitial fluid is drawn into the circulation. Equilibration between the intracellular and extracellular fluid compartments follows. Fluid and electrolyte loss that has occurred over several days will, therefore, have depleted all fluid compartments, and the total deficit may exceed 10 litres in a normal 70 kg patient. There is frequently relative sparing of intracellular fluid.

The sodium and potassium content of gastrointestinal secretions is shown in Table 3.1. Fluid lost from

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Table 3.1 Gastrointestinal secretions ⏎

Secretion	Daily volume (mL)	Na^+ (mmol/L)	K^+ (mmol/L)
Saliva	1,000	10	25
Gastric	1,500	60	10
Bile	500	140	5
Pancreatic	500	140	5
Small bowel	3,000	140	5
Colonic	Minimal	60	30

The values given are only a guide and have also been approximated for simplicity.

burns has a similar high sodium content. Therefore, normal saline is the basic fluid for replacing abnormal fluid losses. As potassium is mainly intracellular, a fall in serum potassium is a late indicator of total body potassium depletion. Therefore, if potassium is known to have been lost, it should be replaced, even if the serum potassium is not below normal. Solutions of 5% dextrose have no place in the replacement of abnormal losses and can only compensate for reduced oral fluid intake.

Fluid replaced into the intravascular compartment must again equilibrate with other compartments, and a too-rapid replacement will merely overload the circulation with deterioration in perfusion and oxygen delivery. Ionotropic support should be considered early in the management of such patients to maintain blood pressure while fluid resuscitation is ongoing. Central venous pressure measurement (typically 3–8 mmHg) and urine output (over 30–50 mL per hour) are good guides during rehydration unless there is associated renal impairment or cardiac failure, when more intensive monitoring may be required.

Cardiorespiratory optimisation Improvements in cardiac output, perfusion and systolic blood pressure should occur as dehydration and hypovolaemic shock are treated. An inefficient cardiac rhythm, such as fast atrial fibrillation, can be controlled by intravenous beta-blockade or digoxin. Congestive cardiac failure may be improved with a fast-acting diuretic or vasodilator. Bronchodilators or steroids may improve bronchospasm. A decision may be taken preoperatively that a patient will require postoperative admission to an intensive care unit for a period of planned artificial ventilation and inotropic cardiac support.

Intensive preoperative maximisation of oxygen delivery requires intensive care monitoring, including measurements of cardiac output and arterial oxygen saturation. An oxygen delivery of 600 mL/minute/m^2 is sought. Fluid replacement, higher inspired oxygen concentrations and inotropes may be needed to achieve this level.

Correction of abnormalities of clotting The patient is usually aware of any inherited coagulation abnormalities. Acquired coagulation defects are more common, particularly in the context of an acutely ill patient. A drug history is important. The patient may be on antiplatelet agents such as aspirin and clopidogrel; direct oral anticoagulants (DOACs) such as dabigatran, rivaroxaban or apixaban; or vitamin K antagonists such as warfarin. Many other drugs, including non-steroidal anti-inflammatory drugs (NSAIDs) and some antidepressants, such as citalopram, are also associated with an increased risk of bleeding.

Measurement of full blood count and a coagulation screen help in the initial assessment when a clotting abnormality is suspected. A low platelet count ($<50 \times 10^9$/L) should be corrected with a platelet transfusion. A prolonged prothrombin time and activated partial thromboplastin time can be corrected by using fresh-frozen plasma or, where appropriate, prothrombin complex concentrates. Patients on warfarin should receive vitamin K in addition to fresh-frozen plasma. Heparin anticoagulation can be stopped and reversed, if necessary, with protamine, although low-molecular-weight heparin (LMWH) may be only partially reversed. Patients taking DOACs, such as rivaroxaban or apixaban, are best discussed with a haematologist, where possible, who can advise on methods of reversal. These may include prothrombin complex concentrate or specific reversal agents depending on the drug in question.

Endocrine abnormalities *Diabetic* patients may be extremely unstable in an emergency situation. Commonly, they are ketoacidotic, but diabetic control will not be fully possible until the necrotic tissue or septic focus has been treated surgically. Surgery has to proceed alongside the management of the patient's ketoacidosis. The occasional patient will be hypoglycaemic from a long-acting oral agent or insulin and a cessation of oral intake. Any patient on oral *steroids* requires parenteral steroid administration at increased dosages.

Antibiotics Many acutely unwell patients have underlying sepsis, and early intravenous administration of a broad-spectrum antibiotic is essential for good outcomes. The antibiotics can subsequently be downgraded or stopped based on the final diagnosis and culture and sensitivity results, which will be available in the coming days.

The 4-day window

A delay of several days allows more formal preparation for surgery. A laparotomy for a non-strangulating bowel obstruction, surgery for obstructive jaundice or an amputation for irreversible ischaemia of a limb may all fall into this category. Medical treatment can be instituted for cardiac failure or hypertension. Preoperative treatment of obstructive airway disease or a respiratory infection, with physiotherapy, bronchodilators and antibiotics, may all be beneficial. Anaemia can be corrected with blood transfusion preoperatively. Perioperative diabetic management can be planned, and diabetic patients on oral agents are usually temporarily converted to insulin. Jaundiced patients are at an increased risk of postoperative renal failure. This is now believed to be mainly secondary to fluid shifts with an overall fluid and electrolyte depletion, which should be corrected preoperatively. Obstructive jaundice classically causes a prolonged prothrombin time, which may reverse with the administration of vitamin K.

Warfarin anticoagulation can be either partially or fully reversed, depending on the thrombotic risk to the patient. When the thrombotic risk is extremely high, the patient is converted to intravenous heparin or LMWH anticoagulation for easier control (see ‘Anticoagulation and antiplatelet therapy’ later in this chapter). There is time for the insertion of an inferior vena cava (IVC) filter if this is indicated. Oral antiplatelet agents and DOACs can be stopped as required (see ‘Anticoagulation and antiplatelet therapy’).

If a patient has had no effective oral intake in the week before surgery, and a gastrointestinal operation is planned, after which oral intake will be further delayed, the institution of intravenous feeding before surgery may be beneficial.

The 4-week window

Most cancer surgery can be delayed for several weeks, without detriment. This allows better medical control of severe hypertension or other cardiorespiratory pathology. There is also time for benefits to accrue from the cessation of smoking. Occasionally, this window must be utilised for the surgical correction of another pathology that, if uncorrected, will make surgery more hazardous. For example, a carotid endarterectomy will greatly reduce the incidence of an intraoperative stroke in a patient with severe carotid stenosis who requires another major procedure. Iron deficiency anaemia can be corrected, reducing the need for perioperative blood transfusion, and contraceptive pills or aspirin therapy can be stopped with normalisation of the risk of thromboembolism or operative bleeding. There is also time to plan the management of patients on anticoagulants and those who have a greatly increased thrombotic risk (see ‘Anticoagulation and antiplatelet therapy’). This period also allows for the initiation of prehabilitation programmes, which enhance outcomes (see ‘Prehabilitation’ later in this chapter).

The over-4-month window

Truly elective surgery should be postponed if the risk of surgery is significant and can be reduced with the passage of time or when some prior medical or surgical intervention will reduce the overall risk. During the first 6 months after a myocardial infarct, the risk of a further infarct in the perioperative period is increased by 30%. A delay of at least 6 months should be observed if the underlying condition does not deteriorate significantly during this period. The risk of a further stroke after a cerebral vascular accident is also increased, and a similar delay is recommended. Patients with obesity are advised weight reduction, which, if successful, can greatly reduce perioperative risk. It may be appropriate to delay surgery until after a carotid endarterectomy, a cardiac valvular replacement, an aortic aneurysm repair, a coronary bypass graft or angioplasty if it is felt that this will reduce the overall mortality or morbidity.

PATIENT INFORMATION AND CONSENT

All patients must be provided with adequate information about their diagnosis and the proposed management plan and must give ‘informed consent’ for the procedure. While informed consent is a legal requirement, it is much more than signing the consent form. It is a process of providing information that enables the patient to decide whether to undergo a specific treatment.

The surgeon must discuss the diagnosis, planned management, alternative strategies, and benefits and complications of the operation with the patient. Any alternatives to surgery should also be discussed. Patients should be able to understand the information provided and make an independent decision. All patients must comprehend the aims, limitations and risks of the surgery that they are to undergo and have the opportunity to request further information if they wish. Striking a balance between providing too much and too little information is challenging, yet is essential for enhancing shared decision-making. Trust remains crucial, as, when a complication arises, it is easy for the patient to assume that a mistake was made or that the surgeons did not do their utmost.

Surgery that alters body image (amputation of a limb, mastectomy or the formation of a stoma) can be particularly distressing. Preoperative counselling by a specialist nurse, patient information leaflets and a visit from a former patient who underwent similar surgery may all be helpful.

The informed consent form, in addition to the aforementioned fields, should also encompass any other information mandated by local regulatory authorities and applicable laws. The regular guidance on 'informed consent' provided by the General Medical Council, local regulatory bodies and various defence organisations is extremely beneficial, particularly as misconceptions continue to exist.

OPTIMISATION OF COMORBID ILLNESSES AND MEDICATIONS

Diabetes

All patients with diabetes should have their blood sugar levels and HbA1c monitored prior to elective surgery. Blood sugars should be well controlled preoperatively, and elective surgery should be postponed until this is achieved.

Surgery in diabetic patients should be planned in the morning, if possible, in order to minimise the disruption to their normal routine and to prevent hypoglycaemia due to prolonged fasting. Diabetic patients should ideally have no residual long-acting insulin or oral hypoglycaemic agents affecting their blood glucose levels at the time of surgery, and the latter should be withheld starting on the morning of surgery. Sodium-glucose cotransport (SGLT 2) inhibitors (e.g. empagliflozin) should be withheld for 3–4 days before surgery. All drugs can be restarted postoperatively once regular oral intake is re-established.

Patients on insulin should be assessed and managed depending on the type of insulin used.[1] Long-acting and intermediate-acting insulins can usually be continued until the night before surgery. Any prandial insulin should be stopped once the patient is fasting. Premixed insulin should be changed to a long-acting insulin or the dose should be reduced or it should be omitted, with appropriate short-acting insulin administered instead.

Patients with type 1 diabetes, along with some patients with type 2 diabetes, may benefit from switching to short-acting soluble insulin within the last 24 hours before surgery. This provides greater flexibility if blood glucose levels fluctuate. The insulin is typically administered as a continuous variable rate infusion (1–3 IU/hour), which is adjusted based on blood glucose levels. Returning to the original regimen should be delayed until normal oral food intake is re-established. Even after minor surgery, the patient must be cautioned that insulin requirements may temporarily increase due to the surgical stress response and heightened steroid production.

Steroid therapy

Preoperatively, a patient may be unable to continue with their oral steroid regime because of restriction of oral intake or poor absorption. An alternative parenteral steroid must be administered. Patients on long-term steroids, whether as replacement therapy or at therapeutic dosage, have suppressed adrenal glands and cannot mount the normal steroid response to stress. Perioperatively, both groups should receive parenteral hydrocortisone, which is then maintained during the postoperative period, initially parenterally and later orally. On the day of surgery, 100 mg of hydrocortisone is administered 1 hour before surgery and subsequently 100 mg is administered every 8 hours. The dosage is decreased as the stress from surgery subsides until the preoperative dose is reached. Even after relatively minor operations, increased steroid levels are needed for several days and, after major procedures, often increased levels are needed for over 2 weeks. Reducing the steroid dosage too rapidly may leave the patient, at best, fatigued and depressed and at worst, in a severe hypotensive Addisonian crisis.

Thyrotoxicosis, phaeochromocytoma and carcinoid syndrome

High levels of circulating thyroxine, adrenaline, noradrenaline or 5-hydroxytryptamine (5-HT, serotonin) can lead to extreme cardiovascular instability in patients during anaesthesia. This situation worsens during surgery to remove a hormone-secreting tumour or an overactive gland, as surgical manipulation may trigger a sudden bolus release of active hormone into the circulation. However, the diagnosis in these patients is usually already established, and the effects of the abnormal secretions can be pharmacologically blocked prior to surgery. The greatest surgical risk lies with patients for whom the diagnosis has not been made preoperatively and who may be undergoing unrelated surgery.

Anticoagulation and antiplatelet therapy

Management of anticoagulation during the perioperative period depends on the indications for therapeutic anticoagulation, the thrombotic risk of the patient and the haemorrhagic risk associated with the surgery. Surgery in a fully anticoagulated patient is likely to be complicated by bleeding, and anticoagulation should be reversed before all elective operations unless the risk of thrombosis is extremely high.

For most patients on warfarin, it can be safely stopped 3 or 4 days before surgery, and the clotting should return to near normal by the time of the procedure.[2] The international normalised ratio is checked immediately before surgery; it should be less than 1.8, even for minor operations, while 1.4 is a safer target. Warfarin can be restarted once the risk of early postoperative bleeding has diminished. After minor surgery, patients can resume their normal medication regimen on the following day. For major surgery, warfarin is withheld for 2–3 days and restarted once the bleeding risk has decreased. Therapeutic levels will gradually restore over several days.

A more urgent reversal of warfarin anticoagulation can be achieved with intravenous vitamin K. This is combined with fresh-frozen plasma or prothrombin complex concentrate when there is greater urgency or when a patient is over-anticoagulated.

Patients at high risk of thrombosis – such as those with a recent personal history of thrombosis, thrombophilic factors or mechanical heart valves – require bridging therapy. They may be started on LMWHs or unfractionated heparin for anticoagulation. LMWHs are easy to administer, either once or twice daily. However, the effects of heparin can be quickly reversed, allowing for safer management of the patient's coagulation status perioperatively. The infusion of unfractionated, short-acting intravenous heparin is simply stopped 1 hour before the surgery. The half-life is only 1.5 hours but, if quicker reversal becomes necessary, protamine can be administered. Cooperation is essential between the surgeon, anaesthetist, cardiologist and haematologist in managing these high-risk patients.

Some patients with contraindications to anticoagulants and a high risk of thrombosis, or those with active deep venous thrombosis (DVT) or a history of pulmonary embolism, may require an IVC filter. IVC filters only protect against pulmonary emboli and do not prevent DVT or complications from thrombus formation on a prosthetic heart valve, within the atria or in an arterial graft. The IVC filter is usually inserted by a radiologist a few days before surgery.

The use of DOACs, including dabigatran (a direct thrombin inhibitor) and rivaroxaban or apixaban (which are factor Xa inhibitors), is on the rise. It is advised to discontinue these medications 24 to 48 hours prior to surgery, depending on the procedure's invasiveness and the bleeding risk. Bridging therapy is not suggested, as the period for withholding the drug is brief and the clinical effects resume quickly upon restarting.[2]

An increasing number of patients are taking low-dose aspirin to prevent thromboembolic events. Aspirin and other antiplatelet agents cause irreversible platelet dysfunction; therefore, haemostasis can return to normal only as new platelets are produced. If these agents are to be discontinued before surgery, at least a week must pass for platelet activity to improve significantly. Stopping aspirin markedly increases the likelihood of perioperative cardiac events in at-risk patients, often outweighing the increased risk of bleeding. Most guidelines recommend continuing low-dose aspirin therapy in patients with cardiovascular disease when the potential increased bleeding risk is considered acceptable.[2]

Clopidogrel should be discontinued 5 days prior to surgery and may be restarted on the second postoperative day. In urgent surgery cases involving patients on clopidogrel, platelet transfusion might be necessary to lower the risk of bleeding.

Medications for other comorbid conditions

- Hypertension should be well controlled, and elective surgery should be postponed until good blood pressure control is established. Antihypertensive medications are continued until the day of surgery, including the morning of surgery.
- Lipid-lowering agents for dyslipidaemia should also be continued until the day before surgery and can be restarted once oral intake has been re-established.
- Patients with hypothyroidism need to continue their thyroxine supplementation, including on the day of surgery.
- Medications such as beta blockers and calcium channel blockers for associated ischaemic heart disease should be continued.
- Medications for bronchial asthma/chronic obstructive pulmonary disease, including inhalers, should be continued, including on the morning of surgery.
- Patients with seizure disorders on antiepileptic medications should continue these. Other drugs such as antidepressants and other psychiatric medications can be continued or stopped based on advice from the anaesthetist and the psychiatrist.
- Management of antiplatelet drugs and other anticoagulants is detailed above.

THROMBOEMBOLIC PROPHYLAXIS

DVT and pulmonary embolism following otherwise successful surgery continue to be significant causes of postoperative mortality and morbidity. Stasis, hypercoagulability and intimal damage are all implicated in the pathophysiology. The incidence can be reduced by assessing the risk in each patient and implementing appropriate physical and pharmacological preventative measures based on the level of risk.

The most important general risk factors for thrombosis include a personal or family history of DVT or pulmonary embolism, immobility, advancing age, obesity, pregnancy and the combined contraceptive pill. Severe infections, inflammatory bowel disease and underlying malignancies also increase the risk of thrombosis. Major additional risk factors are linked to the extent of the operation and the immobility associated with it. In particular, both trauma and surgery involving the hip, pelvis or lower limbs are associated with increased risk.

Preventative strategies can be divided into physical measures that help prevent stasis and pharmacological measures aimed at reducing blood coagulability. Early mobilisation and graduated compression stockings, both during and after surgery, are crucial in preventing postoperative stasis. A variety of mechanical devices that provide intermittent calf compression, either through direct external pressure or by initiating calf muscle contraction with intermittent foot impulse, are available in the operating theatre.

Heparin prophylaxis is the most commonly used pharmacological measure. LMWHs offer the advantage of a longer half-life, allowing for a single daily dose. The regimen is typically initiated on the day before surgery; however, for certain procedures, it may be delayed until after the completion of surgery if there is concern that it could increase haemorrhagic complications.

A scoring system that assigns various weights to risk factors can categorise patients into low-, moderate- and high-risk groups. Popular examples of scoring systems include the Caprini score and the Wells scoring system.

Early mobilisation and graduated compression stockings are recommended for low-risk patients. For patients with a moderate risk of thrombosis, either heparin or intermittent foot impulse is added to the prevention regimen, whereas, in high-risk patients, the two strategies can be used in combination.[3] Additional measures, such as an IVC filter and extended chemical thromboprophylaxis, should also be considered in special circumstances. There is an increasing move towards continuing chemical thromboprophylaxis after discharge from hospital in high-risk patients. For example, most patients undergoing surgery for colorectal cancer in the UK will now be discharged with 28 days of LMWH, which they self-administer at home.

BOWEL PREPARATION AND FASTING

For any general anaesthetic, the stomach should ideally be empty to reduce the risk of aspiration of gastric contents, especially during the induction of, and recovery from, anaesthesia. In elective surgery, standard practice has generally been to enforce a period of 6 hours without food and 2 hours without clear fluids; however, an approach allowing patients to drink small amounts of water until the time of surgery (sometimes known as 'sip til send') has been shown to be safe and to reduce dehydration and patient discomfort, so is increasingly advocated by anaesthetists. Prolonged fasting is not necessary, and apart from patient discomfort and the risk of dehydration, it causes increased postoperative insulin resistance and increased catabolic response to surgery.

However, surgery cannot be delayed for 6 hours in some emergency situations. In addition, a patient with an intestinal obstruction will often not have an empty stomach, even if fasted and if a nasogastric tube is in place. A patient who suffers limb trauma following a meal develops gastric stasis, and the stomach may remain full for many hours. In all of these situations, the anaesthetist has to proceed with the increased risk of a full stomach, taking care to ensure that rapid intubation can be safely achieved.

Preoperative bowel preparation is a critical component of elective colorectal surgery, aimed at minimising postoperative complications and facilitating bowel handling. Mechanical bowel preparation involves using laxatives, such as polyethylene glycol or sodium picosulphate, to clear faecal contents from the colon. Oral antibiotics, such as neomycin and metronidazole, are administered to reduce intraluminal bacteria. The use of mechanical and oral antibiotic bowel preparation in colorectal resections has been a topic of debate, and practice varies significantly. Most current guidelines recommend a combined approach of mechanical bowel preparation and oral antibiotics before elective colorectal resections.[4] For left colonic and rectal surgery, many surgeons advise a phosphate enema if full bowel preparation is not performed. Preoperative bowel preparation is not feasible in cases of intestinal obstruction, and an intraoperative on-table lavage serves as an alternative.

PREHABILITATION

The preoperative period, while a patient awaits surgery, serves as an ideal time to make interventions that significantly enhance outcomes. Prehabilitation programmes are proactive, multidisciplinary approaches aimed at improving a patient's physical and psychological preparedness before surgery. Key aspects of prehabilitation include:

- Exercise training. This encompasses both aerobic and resistance exercises to improve cardiovascular fitness and muscle strength, along with respiratory muscle training.
- Nutritional optimisation. Patients are referred to a dietitian to optimise their diet. Necessary supplements, including vitamins, iron and protein, are also provided.
- Psychological support. Patients undergo assessments for stress, anxiety and depression, receiving appropriate counselling and stress-reduction strategies.

Moreover, all comorbidities can be managed during this time.

Prehabilitation programmes have been demonstrated to minimise postoperative complications, reduce hospital stays and promote functional recovery.[5] The ideal duration for prehabilitation programmes ranges from 2 weeks to 3 months. The success of these programmes also depends on the type of surgery and individual patient factors, making it essential to tailor the prehabilitation programme to the specific surgery and patient.

ENHANCED RECOVERY AFTER SURGERY

ERAS is an evidence-based, multidisciplinary approach during the perioperative period aimed at improving surgical outcomes by reducing the patient's stress response, optimising physiological function and facilitating faster recovery. Originally developed for colorectal surgery, it has now been widely adopted across multiple surgical disciplines.

The elements of ERAS protocols are distributed throughout preoperative, intraoperative and postoperative care. Several key components are highlighted below.

Preoperative phase

- *Patient education*: proper counselling about the surgical procedure, processes and recovery expectations helps reduce patients' anxiety.
- *Optimising health status*: preoperative interventions such as nutritional support, smoking cessation and physical conditioning improve surgical outcomes.
- *Minimal fasting and carbohydrate loading*: allowing clear fluids until surgery and consuming a carbohydrate-loading drink 2 hours prior helps prevent insulin resistance in the postoperative period.

Intraoperative care

- *Anaesthetic techniques*: methods such as opioid-sparing multimodal anaesthesia and regional anaesthesia are utilised.
- *Minimally invasive surgery*: the use of minimally invasive surgery helps decrease tissue trauma and enhance recovery.
- *Goal-directed fluid therapy*: the use of such therapy prevents fluid overload and aids in faster recovery.

Postoperative care

- *Early mobilisation*: this helps to reduce complications such as DVT and pneumonia.
- *Early oral nutrition*: this reduces postoperative ileus and promotes the early recovery of gastrointestinal function.
- *Multimodal pain management*: pain management in this way minimises opioid use and aids in faster recovery.

ERAS has proven to be effective in reducing complications, shortening hospital stays and enhancing patient satisfaction, making it essential for routine implementation in patient care.[6]

INTRAOPERATIVE CARE

Aside from meticulous surgical technique and operative skill, intraoperative care also encompasses several other aspects. In the operating theatre environment, patient safety is the primary concern for surgeons and anaesthetists. In addition to the topics discussed in the following sections, numerous checks have been implemented to prevent the tragedies of mistaken patient identity, the wrong patient undergoing surgery and the equally devastating error of an operation performed on the incorrect side. Reporting and analysing adverse events and 'near-miss' situations to prevent their recurrence is a crucial aspect of patient safety during the intraoperative period.

WHO SURGICAL SAFETY CHECKLIST

The World Health Organization (WHO) *Surgical Safety Checklist* is a structured tool developed to enhance patient safety and reduce surgical complications. The aim of this checklist is to prevent errors, improve communication and ensure essential safety measures are followed before, during and after surgery. The checklist is divided into three phases: sign-in, time out and sign-out:

- The *sign-in* happens before anaesthesia, with the surgical team verifying the patient's identity, the procedure and the surgical site (and side). This process enables the checking of allergies, potential airway risks and blood loss estimation.
- The *time out* before incision verifies patient details, the procedure and imaging, if available. The surgeon discusses critical steps, expected complications, blood loss and concerns, while the anaesthetist and nursing staff address antibiotic administration, equipment readiness and any other concerns.
- The *sign-out* before leaving the theatre confirms the procedures performed, sponge and instrument counts, specimen labelling and postoperative concerns.

The WHO *Surgical Safety Checklist* has significantly reduced complication and mortality rates worldwide and has helped improve surgical outcomes.[7] Hospitals are encouraged to modify the checklist to fit their local needs, and it is mandatory in many hospitals and institutions.

ANAESTHESIA

For nearly all operations, some form of general or regional anaesthesia is essential. Except for local infiltrative anaesthesia, this responsibility mainly lies with the anaesthetists, who also oversee the maintenance of all of the patient's vital functions during the operation. The anaesthetist selects the most suitable anaesthetic, often after consulting with the surgeon, as the intended incision location or the anticipated duration of the procedure can affect this decision. Additionally, the surgeon may require specific intraoperative conditions (e.g. abdominal muscle relaxation or low central venous pressure).

Local infiltrative anaesthesia

Local infiltrative anaesthesia is standard for minor skin or subcutaneous surgeries. It can also be used for major procedures such as inguinal herniorrhaphy, but care must be taken to avoid toxic doses. Local anaesthetic toxicity may lead to convulsions, arrhythmias and cardiac arrest and necessitates immediate management. Handling the peritoneum or spermatic cord may lead to bradycardia, hypotension or vomiting. Thus, patients must be fasted and monitored, and an anaesthetist must be readily available, even if the procedure is being performed under local anaesthetic. This is especially true for older patients with cardiovascular issues. Apprehension or pain increases metabolic demands and adrenaline output, potentially triggering arrhythmias, angina and acute ventricular failure. Combining sedation with local anaesthesia can be risky in these patients, as oversedation may cause confusion, requiring increased sedation to complete the operation. This results in operating on a semi-anaesthetised patient with significant comorbidities, often without adequate monitoring or airway protection.

Peripheral nerve blocks

Lidocaine without adrenaline is infiltrated around a nerve to anaesthetise the tissues it innervates. Direct puncture of the nerve not only is extremely painful but may also cause axonal damage. A good knowledge of anatomy is essential, as major vessels are often in close proximity to major nerves and are in danger of injury. Further reading is recommended for surgeons who are interested in this technique for anything other than digital or intercostal nerve blocks.

Epidural and spinal regional anaesthesia

If possible, an anaesthetist should be responsible for epidural and spinal regional anaesthesia. These techniques cannot be easily instituted, monitored or adjusted by the surgeon, although an occasional isolated surgeon practising in an area with limited healthcare resources may have to compromise. The surgeon establishes the epidural or spinal anaesthetic and then leaves the patient partially under the care of an assistant while proceeding with the surgery, retaining overall responsibility for the anaesthetic issues as well.

General anaesthesia

For most major operations, general anaesthesia is preferred. Inhalational or intravenous drugs, or a combination of both, are used to keep the patient unconscious for the duration of the procedure. Patients may be breathing spontaneously or may be paralysed and mechanically ventilated, but, with either technique, they cannot protect their airway, which is vulnerable to obstruction by the tongue or from the inhalation of vomit or secretions. Laryngeal masks are now used routinely; however, if they are unavailable, a face mask and oral airway, combined with skilful holding of the lower jaw forwards, will also suffice. Nevertheless, only an endotracheal tube provides reliable protection against the inhalation of secretions or gastric contents.

Ketamine has proven to be an extremely safe agent in situations where anaesthetic skills are limited. It provides a state of 'dissociative anaesthesia' – profound analgesia with light sleep – and allows surgery to be conducted on a patient who can still protect their own airway. Slow recovery and unpleasant hallucinations have limited its broader use.

INTRAVENOUS ACCESS

Peripheral vein access is adequate for administering fluids, blood or medications. Central venous access is usually established when hypertonic irritant fluids or medications, such as parenteral nutrition, need to be administered intravenously. Hypertonic solutions can irritate the endothelium and, in a narrow-calibre vein with a small volume flow, they may lead to early phlebitis and vein occlusion with adherent thrombus formation. Central venous access is also required for measuring central venous pressure. While long catheters can be threaded centrally from peripheral veins, direct cannulation of the subclavian or internal jugular vein is preferred.

Percutaneous peripheral vein cannulation

The veins on the dorsum of the hand and forearm are the most suitable. The needle with the overlying plastic cannula is inserted into a vein; the needle is then withdrawn, and the plastic cannula is advanced along the vein's lumen and secured in place. A cannula that crosses a joint may become occluded when the joint is flexed, and movement can lead to increased trauma to the endothelium. The prominent superficial veins in the antecubital fossa, while ideal for emergency access, are, therefore, less suitable for prolonged cannulation. The use of leg veins should be avoided, as cannulation will limit mobility and may increase the risk of DVT.

The lifespan of peripheral cannula access varies significantly. Once phlebitis or fluid extravasation occurs, occlusion becomes unavoidable, and the cannula should be replaced in another vein. Allowing the inevitable occlusion to occur risks severe local reactions and occlusion of adjacent vein segments, which will then be unavailable for future cannulation. Additionally, there is a considerable risk of septicaemia. The lifespan of a cannula can be extended if it is inserted using antiseptic techniques and if endothelial irritation from hypertonic solutions is minimised. Mechanical trauma from movement can be reduced by avoiding the vicinity of joints, and using a small cannula in a large vein results in less endothelial trauma. However, a small cannula is unsuitable for patients requiring rapid fluid or blood replacement.

Peripheral vein 'cut-down'

This technique can provide rapid, large-diameter, secure intravenous access. It may be suitable for shocked patients whose peripheral veins are collapsed and difficult to access, especially when central catheterisation skills are unavailable or have failed. A peripheral vein cut-down also ensures secure intravenous access for several days, which can be hard to achieve, particularly in small children, if suitable plastic cannula or intravenous infusion needles are not available.

A transverse incision is made over a vein. The subcutaneous tissue is opened by sharp or blunt dissection on either side of the vein until artery forceps can be passed beneath it and used to draw a ligature around the vein. This ligature is then tied as distally as possible and a second ligature is passed beneath the vein more proximally. The second ligature is left untied until the cannula is in place. A small incision is made between the ligatures, the plastic or metal cannula is inserted and the second ligature is tied to hold the vein snugly against the outside of the cannula. In a small child, the long saphenous vein at the ankle is the most suitable, as the risk of DVT is not a consideration; this vein is of large calibre and anatomically in a standard position.

Intraosseous access

Intraosseous access was a common route for infusing blood or fluids in children during the early years of the twentieth century. Although it fell into disuse as intravenous techniques improved, it regained popularity in the 1990s as the fastest means of circulatory access in young children. The most suitable site for this procedure is the anteromedial surface of the proximal tibia, located 1–3 cm below the tibial tubercle. An 18- to 20-gauge needle is adequate for infants but, for those over 1 year of age, a 13- to 16-gauge needle is more appropriate. The needle should be rigid to prevent breakage upon insertion into the bone and should include a stylet to avoid marrow plugging the lumen during the insertion process. The needle should be inserted at an angle of approximately 15° from perpendicular, ensuring it is directed away from the tibial growth plate, after which the stylet is removed. This technique can also be applied in adults; however, a drill is necessary. While effective, this procedure carries risks, including the potential for distal limb gangrene.

Central venous catheterisation

Central lines are increasingly utilised in surgical patients. Peripheral thrombophlebitis caused by mechanical and chemical irritation is reduced and the lifespan of access is greatly increased. Multichannel lines, featuring two to five channels, enable monitoring of central venous pressure through one channel, continuous intravenous fluid administration through a second and infusion pump delivery of insulin, heparin or an inotrope through a third. Additional channels can then be utilised for bolus drug administration and blood sample removal.

These lines may be inserted after the induction of anaesthesia as part of perioperative anaesthetic care, or they can be inserted in a conscious patient either pre- or postoperatively. Ultrasound guidance reduces risks and should be used when available. Sterility is mandatory to minimise the risk of infective complications. The patient is placed supine and tilted 15–30° head-down to fill the veins of the neck and the superior mediastinum. Multiple commercial kits for cannulation are available, all of which are based on initially entering the vein with a needle, followed by manoeuvres to safely advance a long catheter into the superior vena cava. It is dangerous to advance the catheter through a needle, as this technique can cut the catheter, resulting in an embolus from the catheter tip. In the *Seldinger technique*, a flexible guide wire is inserted through the needle. The needle is then removed and a long catheter is advanced over the wire, which is finally removed. Intermediate dilating cannulae may be used over the wire if a large-bore catheter is required. An initial small skin incision is essential for threading any catheter over a wire; otherwise, the catheter cannot pass through the skin. In the conscious patient, a bleb of local anaesthetic is infiltrated into the skin, followed by deeper infiltration onto the vein.

Central lines are not without complications. Insertion can be associated with pneumothorax or, occasionally, major haemorrhage. The tip may be advanced too far, which can cause arrhythmias, or it may turn upwards into the jugular veins during a subclavian insertion. An X-ray immediately after insertion is therefore essential to confirm the correct position. Infection of a central line commonly presents with septicaemia, but thrombophlebitis and occlusion can also occur. Full sterile precautions for insertion are thus mandatory. An infected line must be removed and, thus, important access is lost. Multichannel, multipurpose lines, unfortunately, are prone to infectious complications unless all personnel utilising them adhere to similar strict precautions. Single-channel dedicated lines are therefore used when long-term access is needed for prolonged intravenous feeding or the administration of cytotoxic drugs.

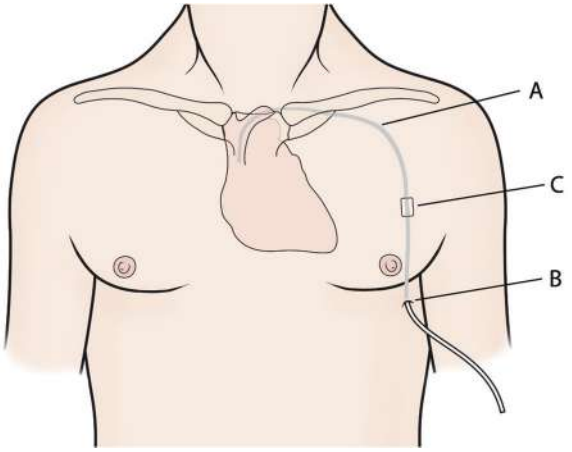
Internal jugular cannulation Anaesthetists prefer internal jugular cannulation, but the position of the cannula is awkward for the conscious patient. The head is turned to the opposite side. The surface marking of the vein runs from the earlobe to the medial end of the clavicle. The vein is overlapped by the sternocleidomastoid muscle but is often palpable in the lower third, where it lies between the sternal and clavicular heads of the muscle. The carotid artery is located posteromedially to the vein. To access the vein, the fingers of the left hand retract the carotid artery medially, and skin entry is made at the apex of the triangle formed by the confluence of the two heads of the sternocleidomastoid. The needle is angled at 30° to the skin and advanced caudally. Resistance is felt, then released, as the needle first encounters the deep fascia and then the vein wall.

Subclavian vein cannulation Subclavian vein cannulation provides the most effective long-term central venous access. The vein runs horizontally behind the clavicle to join the internal jugular vein behind the sternoclavicular joint. It is closely associated with the subclavian artery and the dome of the pleura, along with the underlying lung apex. These structures can be damaged during the insertion of a subclavian line. A sandbag is positioned under the upper thoracic spine to allow the shoulders to fall back, while the arm is retracted downwards to depress the shoulder girdle and the head is turned to the opposite side. The needle is inserted 1 cm below the junction of the middle and outer thirds of the clavicle, angled to pass beneath the clavicle towards the ipsilateral sternoclavicular joint. Insertion on the right side tends to be more straightforward for a right-handed surgeon, while on the left side, advancing the cannula into the optimal position is often easier due to the less acute angle into the superior vena cava. When long-term cannulation is necessary, a subcutaneously tunnelled line, as illustrated in Figure 3.1, can help reduce infection complications.

Peripherally inserted central catheters Peripherally inserted central catheters are long catheters placed in a peripheral vein and advanced to the central veins. Although these fine catheters are not suitable for central venous pressure monitoring, they offer excellent long-term central venous access.

PATIENT POSITIONING

An anaesthetised patient cannot protect their joints from excessive damaging movement. If the patient must be turned, special attention to the neck is crucial. Arms may become trapped or fall unsupported; therefore, they should generally be held straight and adducted alongside the patient's trunk during repositioning. Legs that need to be elevated should be moved together to avoid putting uneven strain on



3.1 A long-term line with a subcutaneous tunnel has fewer infective complications. **A** is the point from which the line is inserted into the subclavian vein. **B** is the exit point of the line through the skin after the additional subcutaneous tunnel has been created. At **C**, there is a Dacron cuff on a portion of the line lying in the subcutaneous tunnel. Reaction around this firmly tethers the line in place. When the line is removed, a small incision must be made at this point to release the cuff. ⏎

the lumbar spine. An unstable position may be necessary for the surgeon to have satisfactory access, and the patient must be secured, for example in a lateral position, with the upper arm supported and the table 'broken'. The ideal position for the surgeon might not be suitable for an anaesthetised patient. For instance, arm abduction should be kept to less than 90° and, if legs need to be elevated for an extended procedure, extreme flexion of knees and hips should be avoided. It is important to remember that patients with regional anaesthesia are equally vulnerable in the paralysed and anaesthetised areas. Even a Lloyd-Davies position can compromise leg perfusion during very long operations, and postoperative calf compartment syndrome is a well-recognised, although fortunately rare, complication. Consideration must be given to mechanical prophylaxis against DVT.

The most vulnerable area of skin is that on which the patient is lying. The initial ischaemic insult in a postoperative sacral or heel pressure sore often occurs during the surgery itself. Pressure damage can be minimised by using a soft surface or a 'jelly mat'. Heel pressure can be further alleviated by distributing the weight-bearing area of skin with soft support under the Achilles tendon. It is also important, during long operations, to tilt the table in different directions to change the pressure points. Localised pressure from restraining straps, armrests and lithotomy poles can also inflict pressure damage to the skin or to a superficial nerve. The ulnar and lateral popliteal nerves are the most susceptible. No skin should touch any metal part of the operating table or its attachments, as this poses a risk of diathermy burns. The eyelids must remain closed to protect the cornea from drying and abrasions.

MONITORING DURING SURGERY

In all operations performed under general anaesthesia, the surgeon is only marginally involved in monitoring the patient's overall homeostasis. However, the anaesthetist needs to determine whether the measurements of urine output or blood loss are realistic. Ascitic fluid mixed with blood and weighed in swabs may be incorrectly recorded as blood and, during open genitourinary surgery, urine output may significantly exceed the amount collected by catheter. A surgical observation that the blood pooling in the pelvis is no longer clotting often precedes confirmation of a clotting abnormality on laboratory tests. Good communication between the surgeon and the anaesthetist throughout the operation is therefore crucial.

In minor surgery under local infiltrative anaesthesia, monitoring may not be necessary; however, when a surgeon operates on an older, comorbid patient for a more major procedure, monitoring becomes essential. An ECG, pulse oximetry and blood pressure monitoring are easy to set up and can alert the surgeon to a deteriorating situation. The patient should also have an intravenous cannula in place in case emergency intravenous access is needed.

INTRAOPERATIVE IMAGING

X-ray monitoring is routine in many urological, orthopaedic, vascular and biliary procedures. A single exposure can demonstrate the position of a fracture after reduction or confirm the free flow of contrast along a vessel, duct or ureter on which surgery has been performed. An image intensifier allows surgery to be conducted with continuous radiological screening to guide the passage of an instrument's tip that is not visible or palpable to the surgeon. Inappropriate or excessive X-ray exposure of both patients and staff must be avoided. The guidelines for safe practice are strict and must be adhered to. Intraoperative ultrasound does not pose these safety hazards but is not universally appropriate.

PREVENTION OF INFECTION

Surgery should be performed in the cleanest environment possible. Floors and surfaces must be washed, and shoes and outer clothing should be changed. Controlled airflow can also decrease the bacterial count in the air. Sterile instruments, sutures and surgical gloves are utilised, and any skin not treated with antiseptic is isolated from the operative field by sterile drapes.

The *'scrub' procedure* involves the antiseptic washing of the hands and forearms of those involved in the surgery. The traditional abrasive scrub is no longer advised, as it damages the skin and increases infection. Instead, hands are washed with a detergent solution that contains added chlorhexidine or an iodine-based antiseptic. Alternatively, an alcohol rub can be used on already clean hands.

Preparing the skin at the operation site with an antiseptic solution is standard practice. Suitable options include iodine-based antiseptics and chlorhexidine dissolved in water or alcohol. Sufficient contact time is necessary for the antiseptic solution to be effective.

Hair obscures the surgeon's view, so removing it from the operative field is standard practice. It must be removed with clippers instead of being shaved, as shaving can cause microabrasions on the skin. If shaving occurs more than a few hours before surgery, it increases bacterial colonisation of hair follicles. Hair should be removed only from the area to be operated on, rather than from a larger field.

Sterilisation of instruments, the use of antiseptic skin preparations, and sterile drapes and towels do not guarantee total sterility. Bacteria are released into the air of the operating theatre from the skin and respiratory tract of everyone present. Masks prevent droplet contamination of the wound if a surgeon sneezes but are largely ineffective in reducing overall air contamination with organisms. If a non-permeable gown becomes saturated with body fluids or if gloves are torn, sterility is compromised, and the chances of infection are raised. Sterile drapes over unprepared skin are not effective barriers if they are permeable and soaked with body fluids. Surgery that opens the gastrointestinal tract is always contaminated.

Sterilisation of instruments

The initial sterility of instruments is mandatory to prevent patient-to-patient transmission of virulent organisms. Instruments exposed to the theatre air will not remain entirely sterile by the end of a prolonged operation. Sterility can be achieved through the destruction of bacteria and viruses via thermal, chemical or irradiation damage. Some organisms exhibit greater resistance to sterilisation methods than others, which determines the basis for sterilisation schedules. The choice of method is often influenced by the properties of the material or instrument being sterilised. Heat-tolerant materials and instruments can be sterilised using pressurised steam. The higher the temperature, the shorter the duration for which it must be maintained to achieve sterilisation, and several alternative cycles are available in standard autoclaves. The cycle begins with vacuum extraction of air, except in small, portable steam sterilisers. These may fail to sterilise an instrument with a lumen where the air is trapped and steam cannot penetrate. Heat without steam is less effective, requiring temperatures of 180°C for 60 minutes.

Commercially, ethylene oxide gas and irradiation are used to sterilise single-use instruments and equipment. Instruments such as fibreoptic telescopes can be damaged by the temperatures required for steam sterilisation. Aqueous solutions of formaldehyde or glutaraldehyde are the most common alternatives used in hospitals for multi-use, heat-intolerant equipment. Unfortunately, these methods do not eliminate all spores and viruses and should be regarded as disinfection rather than sterilisation procedures.

Antibiotic prophylaxis

Despite all of the above measures, infectious complications continue to be a significant source of postoperative morbidity in some procedures unless prophylactic antibiotic therapy is employed. The therapy is founded on the principle that bacterial contamination can occur during surgery and that the timing of antibiotic administration for prevention is crucial to ensure optimal blood levels during the operation.

Antibiotic prophylaxis is ideally administered about 60 minutes before skin incision. The dose of antibiotics should be repeated every 4–6 hours in long operations or in cases of excessive blood loss. Extending prophylaxis into the postoperative period does not offer much benefit. The choice of antibiotic is determined by the likely pathogenic contaminants and local sensitivity patterns.[8]

Special attention should be given to patients who may be immunocompromised, whether due to treatment with immunosuppressants or chemotherapy, or because of underlying conditions such as human immunodeficiency virus (HIV) infection, prior splenectomy or a haematological malignancy. It is important to note that in patients with haematological malignancies, a normal white blood cell (WBC) count does not ensure normal function. Furthermore, repeated splenic infarction in sickle cell disease or a myeloproliferative disorder can lead to hyposplenism from autosplenectomy. Another group of patients requiring close observation includes those at increased risk of developing infections related to prosthetic joints, vascular grafts, or damaged or prosthetic heart valves.

Anti-staphylococcal prophylaxis Anti-staphylococcal prophylaxis is considered when the source of infection may be the patient's own skin or upper respiratory tract or that of the personnel in the theatre. The incidence of infection is low in clean surgery; however, antibiotic prophylaxis is recommended if foreign material is used, as infections related to joint prostheses, arterial grafts or mesh in hernia repairs can all have disastrous consequences. The emergence of methicillin-resistant *Staphylococcus aureus* (MRSA) has created increasing challenges in providing effective anti-staphylococcal prophylaxis without the inappropriate use of 'second-line' antibiotics, which should be reserved for treating severe infections with resistant organisms.

Intestinal organisms Intestinal organisms encompass a wide variety of potential pathogens, many of which are anaerobic. Antibiotic prophylaxis is advised for all surgeries involving the opening of the gastrointestinal tract, and it is especially crucial in colonic surgery. A combination of broad-spectrum antibiotics effective against Gram-negative organisms and anaerobes is commonly employed.

Urology A transient bacteraemia is common in urethral instrumentation, even in an apparently non-infected urinary tract, and occasionally progresses to bacteraemic shock. This serious complication can be almost eliminated by administering a single dose of an appropriate antibiotic before instrumentation.

Endocarditis The risk of endocarditis is highest in patients with cardiac valvular lesions or a cardiac valve replacement, but prosthetic vascular grafts are also at risk. At-risk patients require antibiotic prophylaxis against potential pathogens. In the oral cavity, anaerobic streptococci, which are sensitive to amoxicillin, are the most common pathogens, although other organisms may also be involved. Consequently, dental surgery presents the highest risk, but any general anaesthetic can lead to bacteraemia with oral organisms, including *Streptococcus viridans*. In the case of gastrointestinal or urinary tract surgery, antibiotic prophylaxis should additionally cover Gram-negative and anaerobic organisms.

Viruses Viruses pose a threat to the safety of all surgeries. The long latent period before clinical symptoms and the serious, frequently fatal consequences of infection are major concerns. Hepatitis and HIV can be transmitted through small quantities of infected blood or tissue fluid, with needlestick injuries primarily responsible for infections between operating personnel and patients. Universal precautions, including the use of double gloves and impermeable gowns, should be practised. Great care must be taken in the handling of needles and scalpels during every operation, and eye protection is also recommended. Utilising diathermy for skin incisions and dissection, employing blunt needles for fascial closures and using clips for skin closures can significantly reduce the risk by eliminating sharp instruments from the procedure.

All surgeons should be immunised against hepatitis B. Immunisation for hepatitis C and HIV is not currently available, but HIV prophylaxis should be initiated after a needlestick injury involving contamination from a known HIV carrier.

Surgery for infective pathology Antibiotics in this situation are prescribed to treat rather than merely to prevent infection and must therefore be administered for an adequate period of time. This duration can range from a 5-day course to 2 weeks or more, depending on the underlying condition, the ability to perform source control and the patient's general condition. Broad-spectrum antibacterial activity is essential until bacteriological results are available, and adequate blood levels can often be assured only with parenteral administration.

BLOOD TRANSFUSION

Blood has been used to treat haemorrhage since the early twentieth century. Patient attitudes towards blood transfusions vary, and specific preoperative consent is mandatory. Blood can be separated into its components for individual use: red cells, platelet concentrates, fresh-frozen plasma, cryoprecipitate, albumin, high-purity factor VIII and combination factors are available. Component therapy should be the default, while whole blood is rarely used except in cases of massive trauma. Transfusion triggers for blood and component therapy are well defined and should be followed.[9]

The preselection and screening of donors and donated blood for blood-borne pathogens are crucial. However, the risk of infection remains. Providing safe blood requires a high level of organisation and strict protocols. If an accredited blood transfusion service is unavailable, avoiding blood products unless absolutely necessary is extremely important. Unnecessary transfusions, such as those that occur when preoperative anaemia could have been corrected or a drug associated with bleeding could have been stopped, must be avoided.

Blood banks

When an accredited blood bank transfusion service is available, it provides a safe source of blood for the surgeon, who does not require an in-depth understanding of blood collection, storage and compatibility testing. However, it is crucial to remember that the most common cause of a serious transfusion reaction is either the incorrect labelling of the blood sample sent from a patient for cross-matching or the failure to ensure that the blood from the blood bank is administered to the right patient. The importance of adhering to all checking procedures in the ward or operating theatre cannot be overstated.

Whenever possible, blood should be ordered from the blood bank in advance to allow all antibody and compatibility tests to be conducted. Thus, the potential need for a blood transfusion during an operation should be addressed preoperatively. If a transfusion is deemed unlikely, the patient's blood must be sent for grouping and antibody testing. Should the patient require a transfusion, blood can be issued from the blood bank within 30 minutes with a high level of safety.

The presence of antibodies – more common after multiple previous transfusions – may necessitate the pre-ordering of specific blood. Although it is rare to transfuse blood without some form of emergency compatibility test, it is permissible to transfuse non-cross-matched group O rhesus-negative blood in cases of massive blood loss. Nonetheless, there remains a risk of reactions to other antigens, particularly in patients with a history of prior transfusions.

Transfusion reactions

A transfusion reaction occurs when the patient's immune system or body reacts negatively to a transfusion. This may manifest as pyrexia, shock, urticaria, headache or backache. Initially, it is often unclear whether it is a haemolytic transfusion reaction, a minor allergic or febrile reaction, bacteraemia from contamination or an unrelated deterioration in the patient's condition. The initial management of all suspected reactions involves discontinuing the blood transfusion, followed by assessment. The blood bank should be informed immediately. During anaesthesia and surgery, diagnosing a transfusion reaction is more challenging, as there are multiple potential causes for pyrexia, cardiovascular instability or allergic reactions:

- An *allergic reaction* is rarely severe enough to require adrenaline and steroids. A minor reaction can be treated with antihistamines.
- A *febrile reaction* used to occur commonly, particularly with patients who had received multiple transfusions, due to sensitisation to platelet or leucocyte antigens. The use of leucocyte-depleted blood has made this reaction rare. A red cell mismatch must be ruled out.
- A *haemolytic transfusion reaction* due to ABO incompatibility is linked to a high mortality rate. It may commence after only a small volume of blood has been transfused. Shock, rigors and back pain are common symptoms. The immediate risks include shock, hyperkalaemia and renal failure. Treatment focuses on supportive resuscitation, which includes intravenous hydrocortisone and maintaining adequate urine output. Dialysis may become necessary.
- A *delayed haemolytic transfusion reaction* may arise from minor blood group incompatibilities. A few days after the transfusion, the patient becomes jaundiced and anaemic with a low-grade fever. Treatment is supportive.

Autologous transfusions

Some hazards of blood transfusion can be avoided by using the patient's own blood. However, this has not become common practice, as it requires significant infrastructure to implement successfully. There are three methods to achieve this, but each has inherent limitations. Bacterial contamination and infection remain a risk:

- *Preoperative donation*, over a period of 5 to 6 weeks, can accumulate 2 to 4 units of the patient's own blood, available for transfusion during surgery. The operation must be reliably scheduled, and the patient should be fit to undergo repeated venesection without risk. Oral iron and additional erythropoietin will aid the patient in recovering a normal haemoglobin level more swiftly.
- *Acute normovolaemic haemodilution* immediately before surgery involves withdrawing 2 units of blood and replacing it with three times the volume of crystalloid. The blood available for transfusion is fresh and contains active platelets and clotting factors. However, it is seldom possible to withdraw more than 2 units in this manner.
- *Intraoperative blood salvage* with reinfusion into the patient can be an excellent technique for conserving blood. It is sometimes employed in an elective setting for knee surgery. In emergency situations, massive haemorrhage into the peritoneal or pleural cavity is typically the only circumstance in which it is practical. It is unsuitable if the blood is contaminated with gastrointestinal bacteria or malignant cells. In its simplest form, the blood is drawn into an evacuated container containing citrate anticoagulant, then returned to the patient through a blood filter. The disadvantages of the technique in emergencies include the challenges of setting up blood collection on an occasional basis in situations with exsanguinating haemorrhage. Additionally, there are dangers associated with the infusion of activated clotting factors and bacterial contamination. More advanced systems can wash and filter the blood before reinfusion. This may involve a *cell washer* in the theatre, or the blood can be collected and transported to a central site for processing. However, the delays involved make these refinements less suitable in emergencies.

POSTOPERATIVE CARE

The surgeon is responsible for the majority of postoperative care. Suboptimal care can negate the advantages of good surgery.

LEVEL OF CARE

The appropriate level should be considered preoperatively, and the decision should be reviewed at the completion of surgery if unexpected problems have been encountered.

Day surgery

Patients who are ambulant and can resume normal oral intake within a few hours may return home. There should be no anticipated metabolic or cardiovascular instability and no expected respiratory compromise. Satisfactory pain relief must be achievable with agents that are suitable for use at home. After a general anaesthetic and following more major operations under local anaesthesia, patients must have a responsible adult who can care for them for the first 24 hours. The patient should know the emergency management procedures for any complications that might arise at home. However, if a complication would still be significantly more serious outside the hospital environment, the advisability of discharge home should be reassessed.

Surgical ward

A surgical ward provides a suitable environment for patients who need nursing care, basic monitoring of vital functions and pain relief or other treatments that cannot be managed at home:

- *Nursing care* may include the management of open wounds and the challenges associated with urinary catheters, stomas, nasogastric tubes, and chest or abdominal drains. Alternatively, it may focus on the basic care of an immobile patient.
- *Monitoring* blood pressure, pulse, temperature, urine output and fluid balance are all standard ward procedures. Blood glucose levels can be monitored in patients with diabetes, and the measurement of oxygen saturation and central venous pressure is also practical. More advanced monitoring requires a more intensive environment.
- *Pain relief* through patient-controlled intravenous opioids or via an epidural infusion is impractical at home; however, both can be effectively managed in a suitable surgical ward environment.
- *Other treatments*, although impractical at home, can be safely managed in a regular ward. Intravenous fluid replacement and parenteral feeding are straightforward unless the patient is cardiovascularly or metabolically unstable. Minor respiratory compromise can be treated with oxygen therapy and chest physiotherapy.

Intensive care or high-dependency environments

Intensive care or high-dependency environments are necessary when a patient is cardiovascularly unstable or has incipient or established respiratory or renal failure. The definition of these units varies across different localities, as does the quality of medical supervision. The surgeon, anaesthetist or medical intensivist may serve as the lead clinician, but the ongoing involvement of the surgeon is crucial. Patients requiring mechanical ventilation, inotrope support or dialysis are clearly candidates for this environment; however, those experiencing incipient cardiac, respiratory or renal failure often have a better prognosis if transferred early to a setting where intensive monitoring and intervention are available.

PAIN CONTROL

Patients fear pain after surgery, and managing it is crucial to minimise the distress it causes. Additionally, unmanaged pain hinders recovery and increases postoperative complications. Pain resulting from chest and upper abdominal incisions impairs both effective respiratory effort and the clearance of secretions. Controlling pain lowers the occurrence of postoperative chest infections. Pain following abdominal incisions significantly contributes to postoperative ileus, and the reduction of this complication in laparoscopic surgery is likely partly due to decreased abdominal wall wound pain. Furthermore, pain is linked to many of the bothersome postoperative nausea and hypotensive episodes that hinder satisfactory discharge after day surgery.

Oral analgesia

Oral analgesia is the mainstay for day surgery pain relief. A combination of an NSAID with a preparation of paracetamol and an opiate proves satisfactory in most patients. Pain control can be improved by commencing analgesic drugs immediately prior to surgery. Patients in whom an NSAID is contraindicated will require an increased dosage of opiates. This may cause nausea and should be anticipated with an oral anti-emetic. Postoperative nausea and vomiting also prevent the satisfactory administration of oral pain relief.

Local anaesthetic infiltration

Local infiltration of bupivacaine into the wound or laparoscopy port sites provides excellent pain relief in the critical first 6 hours after surgery. It may be more effective if given at the start rather than the end of the operation. This technique is used extensively in day surgery but is less effective in a long abdominal or thoracic wound where both superficial and deep anaesthesia are required. Further bupivacaine can be administered to prolong the anaesthesia if a wound catheter is left *in situ*.

Intramuscular opiates

Opiates were, for many years, the mainstay of postoperative inpatient pain relief. They are administered as bolus injections as and when required or at regular intervals. The requirement is usually higher in the immediate postoperative period, with the need decreasing over the next few days. This approach is satisfactory for patients who are expected to need only a few boluses and who are anticipated to be ambulant and capable of taking oral medication within 24–48 hours. However, if severe prolonged pain is expected, this method becomes inadequate, as it leads to significantly fluctuating levels of pain relief, even with regular dosing. Hourly boluses are safe if the patient continues to experience pain, but the situation must be closely monitored to avoid the risk of overdose.

Intravenous opiates

This is the fastest way to control severe pain. A 2.5 mg dose of intravenous morphine is safe for an adult experiencing severe pain and can be repeated at 5-minute intervals, if necessary, up to a total of 10 mg or more. Once the pain is under control, a longer term strategy for adequate pain relief can be implemented.

Patient-controlled analgesia

Patient-controlled analgesia is a system for delivering intravenous opiates, with the dosage controlled by the patient. The patient can administer a bolus (usually 1 mg for adults) by pressing the control button. This system allows patients to manage their pain without the risk of overdose, as it includes a built-in safety ‘lock-out’ feature to prevent the rapid delivery of repeated boluses. Typically, a 5-minute period during which the system will not respond to a second request for a bolus is sufficient. The patient-controlled analgesia pump can also be adjusted to deliver a background infusion of analgesics, and patients can request additional boluses beyond this baseline if needed.

Epidural analgesia

Epidural analgesia is an extremely effective method of ensuring a pain-free early postoperative period after major abdominal or thoracic surgery, while avoiding the sedation and other side effects caused by systemic opiates. An anaesthetist places an epidural catheter, and analgesia is maintained through the continuous infusion of local anaesthetic agents or opiates into the epidural space. The excellent pain control that results can reduce postoperative respiratory complications and allows the patient to turn and move more freely. Analgesia can be sustained without causing distal paralysis or paresis. However, epidural pain relief is not without complications. Overdosage can lead to hypotension, and failure of delivery from a blocked or misplaced catheter can cause severe breakthrough pain, which is sometimes difficult to control. Infection in the epidural space poses a significant risk. Catheters must be placed under sterile conditions, and precautions should be taken to prevent subsequent infection. An epidural catheter should be removed as soon as it is no longer needed. An epidural haematoma is a rare but potentially catastrophic complication. The signs of cord compression from an expanding haematoma may be mistaken for the effects of the epidural infusion until cord damage becomes irreversible. Management involves early recognition of the possibility of an epidural haematoma, confirmatory imaging and urgent neurosurgical transfer for cord decompression. Prevention includes good insertion technique and avoiding epidural anaesthesia or analgesia in patients with underlying clotting abnormalities. Epidural catheters should not be inserted or removed within 12 hours of LMWH thromboprophylaxis administration.

Intravenous fluid requirement

Despite enhanced recovery programmes, many postoperative patients remain unable to ingest oral fluids for several days. Intravenous maintenance requirements for adults and children are outlined in Table 3.2. Additionally, fluids and electrolytes must be administered to address pre-existing dehydration and replace ongoing abnormal fluid losses. Calculating the appropriate volumes can be difficult in the early postoperative phase. Fluid shifts may also cause an imbalance, with hypovolaemia linked to increased interstitial fluid. An adequate circulatory volume, central venous pressure and urine output can only be sustained by achieving a positive fluid balance. Conversely, increased secretion of antidiuretic hormone postoperatively inhibits the elimination of excess intravascular fluid, and subsequent fluid overload, particularly in older people, can trigger congestive heart failure.

In adult practice, maintenance fluid and electrolyte requirements are rarely calculated accurately based on weight. Instead, a standard regimen of 2–3 L of fluid is administered, of which one-third to one-quarter consists of normal saline, with the remainder as 5% dextrose. These solutions often include potassium (usually at 40 mmol/L), but potassium can also be added in aliquots of 27 mmol. Consequently, a small, older patient would receive 500 mL of saline and 1.5 L of 5% dextrose for maintenance, while a large,

Table 3.2 Daily intravenous maintenance requirements for babies, children and adults ⏎

Water	Sodium	Potassium
100 mL/kg for the first 10 kg	1.5–2.0 mmol/kg	1.0 mmol/kg
+50 mL/kg for the second 10 kg	–	–
+25 mL/kg for each subsequent 10 kg	–	–

Table 3.3 Maintenance regimens ⏎

Body weight/ Status	Total intake	Fluid	Sodium
40-kg older woman	1.5 L dextrose 500 mL saline 54 mmol K^+	2 L	70 mmol (1.5–2.0 mmol/ kg)
80-kg young man	2 L dextrose 1 L saline 81 mmol K^+	3 L	140 mmol (1.5–2.0 mmol/ kg)

younger patient would receive 1 L of saline and 2 L of 5% dextrose (Table 3.3).

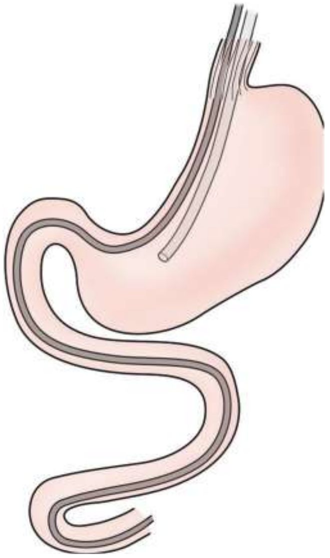
PERIOPERATIVE NUTRITION

Cardiac, respiratory and renal failure are all well recognised by clinicians as life-threatening conditions for which medical intervention is indicated to reduce mortality. Nutritional failure presents more insidiously and, although eventually equally serious, is often ignored. Starvation or nutritional failure is a contributory cause of death in many patients who die in hospital of complications some weeks after surgery. This is of particular relevance in gastrointestinal surgery. The simpler and more satisfactory option of enteral feeding should always be considered; however, it may not be practical in the presence of gastrointestinal complications, and parenteral feeding has to be instituted.

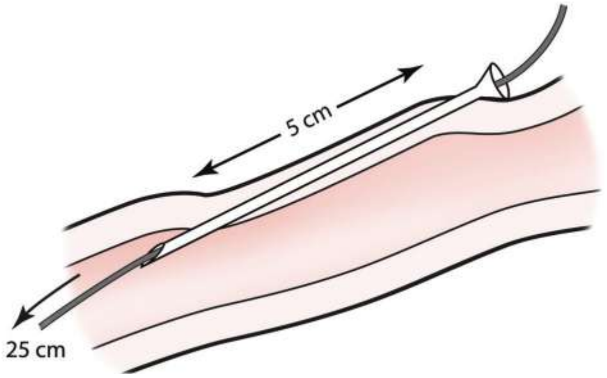
Enteral feeding

Enteral feeding is preferable to intravenous feeding, provided the gut is functioning, and should always be considered; however, it is unfortunately often not feasible or is contraindicated. Enteral feeding has the advantage that the portal circulation is not bypassed and, in addition, it preserves the luminal delivery of nutrients to the gut mucosa. This is now known to be important in the prevention of enterocyte and colonocyte dysfunction. The septic complications of intravenous feeding are also avoided. If there is upper gastrointestinal dysfunction, it may still be possible to feed enterally if the feed is delivered more distally. For example, if a prolonged gastric ileus is anticipated, a *long double-lumen nasogastric tube* can be passed during the operation. The surgeon guides the long end through the duodenum into the first loop of jejunum. The shorter end remains in the stomach for gastric aspiration (Figure 3.2). Alternatively, a *feeding enterostomy* may be introduced directly into the jejunum at the time of surgery. This form of feeding jejunostomy has the advantage of sparing the patient a nasogastric tube solely for the purpose of feeding, but the jejunal puncture and fixation of the jejunum to the abdominal wall have the potential for complications. A needle is introduced obliquely through the jejunal wall through which a catheter is threaded (Figure 3.3). The needle is withdrawn and a purse-string suture inserted. A similar needle is then used to guide the catheter through the abdominal wall. The jejunum is then fixed to the abdominal wall to prevent kinking.

Enteral feeding should be introduced slowly and increased as tolerated. Long-term gastrostomy feeding may be indicated in patients with oesophageal pathology and also in patients with dysphagia secondary to

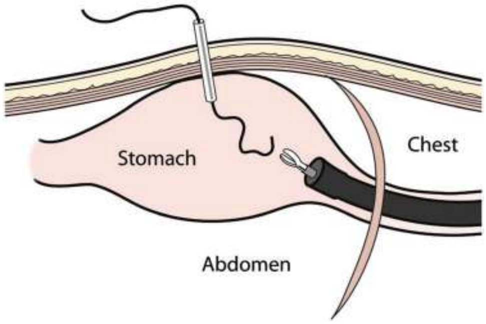


3.2 A double-lumen nasogastric tube is placed so that the short tube is in the stomach for gastric aspiration. The longer tube should lie through the duodenum, well into the first loop of jejunum. More proximal positioning will result in reflux of jejunal feed into the stomach. ⏎



3.3 A 7 cm long, 16-gauge needle is introduced through the jejunal wall so that there is a 5 cm intramural track. A catheter is threaded through the needle and then distally within the lumen for a further 25 cm. ⏎

neurological disorders. The *feeding gastrostomy tube* can be introduced by the percutaneous endoscopic approach (Figure 3.4) and can be established in the endoscopy suite under sedation and local anaesthesia. Techniques vary with different devices, but one method is illustrated in Figure 3.4. An open gastrostomy is described in Chapter 7.



3.4 Percutaneous endoscopic gastrostomy (PEG). The gastroscope is used to distend the stomach and elevate it against the anterior abdominal wall. A cannula is introduced into the stomach through a small incision made under local anaesthesia. A thread is then passed through the cannula, gripped through the gastroscope, and delivered out through the mouth where it is attached to the gastrostomy tube, which is then gently pulled down into place. ⏎

Parenteral feeding

Solutions of amino acids, glucose and emulsions of lipids form the basis of intravenous feeding. It is now standard practice to combine lipids, glucose and amino acids in a single bag, to which a customised amount of additional electrolytes, vitamins and trace elements is added. These three-chamber bags are readily available, and the components are mixed just before infusion. The solutions used for parenteral nutrition are hypertonic and irritant to peripheral veins; therefore, a central venous line is usually established. Sterility is paramount, as infection can lead to septicaemia and central vein thrombosis. A feeding line should thus be a dedicated line and not used for intravenous access for other purposes. For long-term feeding, a length of tunnelled line can be placed subcutaneously to reduce septic complications and prolong the life of the line, as discussed earlier in this chapter.

Energy Food serves as fuel for the body. Carbohydrates provide approximately 4 kcal/g, while fats supply 9 kcal/g. Although fat appears to be a more efficient fuel source, it cannot be metabolised effectively on its own. Therefore, providing nutritional support to an obese patient remains crucial. Protein, often overlooked in calculations, contributes roughly 4 kcal/g upon breakdown, with nitrogen released to be excreted as urea. Consequently, skeletal muscle becomes a significant fuel source in starved patients. However, some of the amino acids administered intravenously during well-balanced parenteral nutrition should be allocated for enzyme replacement and structural repair. Every cell in the body requires fuel for maintaining cell membrane functions, as well as for essential mechanical and enzymatic processes within the cell. Cells engaged in vital metabolic functions for the entire body require proportionally more; for example, the liver accounts for 26% of the total basal metabolic requirements in the resting state.

Specific nutrients Food is essential for providing specific nutrients necessary for chemical reactions and for the structural integrity of both intra- and extracellular materials. Amino acids are the most important building blocks of tissue, but lipids and carbohydrates are also required for structural mucopolysaccharides, glycoproteins and glycolipids. The balance of amino acids is particularly critical when feeding a very ill patient with an already compromised metabolism. Although some imbalances can be partially addressed by metabolic pathways that convert one amino acid into another, challenges remain. Certain ‘essential’ amino acids cannot be produced by normal human metabolic pathways. Others, deemed ‘conditionally essential’, can only be synthesised under optimal metabolic conditions. Furthermore, a poorly balanced combination places additional strain on the patient’s already compromised metabolic pathways. Often, an excess of amino acids is simply broken down and lost from the amino acid pool and, while some protein calories are extracted, the nitrogen must be excreted, further burdening suboptimal hepatic and renal function.

Daily requirements Daily energy and nutrient requirements are typically based on body weight, although calculating by lean body mass may be more suitable:

- *Basic energy requirements* are approximately 25 to 30 kcal/kg of body weight per day (1,800 to 2,100 kcal/day for a 70 kg man).
- *Protein requirement* is estimated at approximately 1 g/kg/day (70 g/day for a 70 kg man), although 0.8 g/kg/day is generally sufficient (56 g/day for a 70 kg man).

There are various concentrations of premixed parenteral nutrition available. The most commonly used formulations are compounded bags that contain lipids, amino acids and carbohydrates, along with all of the trace elements and vitamins. The exact volume and calorie content may vary, but a 2 L bag typically provides about 2,000 calories.

Many postoperative patients for whom oral feeding is delayed due to a prolonged ileus only require a simple, basic maintenance regimen, as outlined above, for a period of 1 to 2 weeks. The temptation to overfeed a severely malnourished patient must be resisted. Initially, their daily requirements are *less*, not more, than the standard requirements. A process of *'reductive adaptation'* occurs. Enzyme reserves are reduced, leading to increased cellular efficiency. A sudden increase in nutrients exceeds the metabolic capacity of the cells, resulting in damage from toxic metabolites that the cells are unable to clear (re-feeding syndrome).[10] Any electrolyte abnormalities should be corrected before re-feeding, which must be introduced very gradually.

Long-term parenteral feeding Long-term parenteral feeding may be required for established intestinal failure. The need for micronutrients, trace elements and vitamins becomes increasingly important, and patient care is usually managed by specialist nutrition teams.

POSTOPERATIVE COMPLICATIONS

RESPIRATORY COMPLICATIONS

Postoperative respiratory complications are one of the leading causes of morbidity and mortality. Many patients already have some degree of respiratory compromise preoperatively, but respiratory function is further challenged by general anaesthetic and surgery. In general, the management of respiratory complications consists of correcting mechanical problems, ensuring adequate pain relief, providing intensive physiotherapy, administering antibiotics and supplying additional oxygen in the inspired air. If, despite these measures, the P_aO_2 falls below 8 kPa or the P_aCO_2 rises above 7 kPa, then mechanical ventilation should be considered.

Atelectasis

Anaesthetic gases irritate the respiratory epithelium, and an increase in bronchial secretions is expected. Impaired clearance of secretions is common postoperatively. Not only does this predispose the patient to a postoperative respiratory infection, but a plug of mucus can occlude a segmental or even a main bronchus, leading to atelectatic collapse distally. Coughing may be too painful and, once analgesia is adequate, the patient may be too sedated to wish to cough unless encouraged. Therefore, adequate analgesia and regular, well-timed chest physiotherapy are essential. Patients should be encouraged to use incentive spirometry with the help of a portable spirometer. An established mucous plug may be treated by dislodgement through intensive physiotherapy, but bronchoscopy is sometimes still indicated.

Mechanical failure

Mechanical failure of adequate ventilation due to a pleural space filled with air, fluid or blood must be ruled out. Tidal volume can also be diminished by a diaphragm that is splinted by raised intra-abdominal pressure. When gastric dilatation partially contributes to the issue, this situation can be improved by gastric aspiration.

Acute respiratory distress syndrome

Acute respiratory distress syndrome is a widespread lung injury that occurs 24 to 72 hours after various initial insults. General opacification of the lung fields on X-ray is evident, and the decline in respiratory function often necessitates mechanical ventilation.

Chest infections

Chest infections are a common postoperative complication. The normal commensals of the upper respiratory tract can become opportunistic pathogens due to the increased stagnant secretions in the lower tract. A respiratory tract infection is the most common cause of fever during the first 3 days after surgery. A pulmonary embolus may also present with dyspnoea and pleuritic chest pain. Distinguishing it from an infectious problem can be challenging when symptoms, signs and X-rays indicate an area of pneumonia.

CARDIOVASCULAR COMPLICATIONS

Strokes and myocardial infarctions

Cardiovascular instability, especially periods of hypotension, can be potentially serious in any patient with stenosis of an artery supplying the myocardium or brain. A perioperative myocardial infarction or cerebrovascular accident may follow an episode of poor perfusion before, during or immediately after an operation. Additionally, the increased coagulability of the blood during the postoperative period predisposes individuals to arterial thrombosis in stenosed arteries, which may again be triggered by a drop in perfusion. This drop may be linked to secondary postoperative haemorrhage or sepsis from an anastomotic leak. The surgeon must be aware of this combination of pathologies; otherwise, only the secondary medical problem may be diagnosed, while the underlying surgically amenable complication could be overlooked.

Cardiac failure and inotrope support

Cardiac output and arterial blood pressure may both be depressed in an ill patient. When the perfusion of vital organs is threatened, inotropic support with adrenaline, noradrenaline or other pressor agents becomes necessary. Such patients require intensive monitoring and often mechanical ventilation, and they will need to be transferred to an intensive care unit.

Venous thrombosis and embolus

The prophylaxis of venous thrombosis and pulmonary embolus have already been discussed in this chapter. These measures should continue during the postoperative period until the patient is fully mobile and often for a more extended period in high-risk patients. A clinical diagnosis of DVT is challenging, as the signs are often unreliable. However, various algorithms have been developed to assist in management decisions. D-Dimer levels have a negative predictive value and are therefore not useful during the perioperative period when they are already elevated. Doppler ultrasound, performed by an experienced operator, is a sensitive investigation and has nearly replaced the old ‘gold standard’ venography. The treatment for an established thrombosis or embolus is anticoagulation.

Accurate clinical diagnosis of pulmonary embolism is challenging. Treatment often needs to begin with a presumptive diagnosis, relying on clinical suspicion combined with an analysis of ECG or blood gas results. Subsequently, radiological investigations play a crucial role in establishing the diagnosis; if a pulmonary embolism is excluded, treatment can be halted, thereby avoiding several months of additional prophylactic anticoagulation therapy. The choice of investigations will depend on the available facilities. Computed tomography pulmonary angiography is currently regarded as the gold standard, but ventilation–perfusion (VQ) scanning is still utilised in some cases.

Initial treatment is with non-fractionated heparin, LMWH or fondaparinux. Local protocols may vary; however, a typical loading dose of 10,000 units of non-fractionated heparin (100–200 units/kg) is administered intravenously, followed by a heparin infusion of 30,000 units over 24 hours, adjusted in line with monitoring. After confirming the diagnosis, warfarin anticoagulation is initiated unless there is a persistent risk of postoperative bleeding. Heparin is discontinued once the patient is fully anticoagulated, and warfarin should be continued for 3–6 months. A large pulmonary embolus with right heart failure may require more active treatment with thrombolysis via a pulmonary artery catheter placed by a radiologist. The surgical alternative of pulmonary embolectomy is almost never undertaken. An IVC filter should be considered for patients at high risk of additional emboli, such as those with a free-floating IVC clot, those experiencing repeat emboli after the initiation of heparin or those for whom anticoagulation is contraindicated.

RENAL COMPLICATIONS

Oliguria

Oliguria, typically defined as urinary output of less than 20 mL per hour (or <0.5 mL/kg/hour), necessitates action. First, urinary retention or a blocked catheter must be ruled out. If the patient is hypotensive or in shock, volume replacement of the extracellular fluid compartment is the top priority. Likewise, if oliguria is due to poor perfusion from cardiac failure, this should be addressed. If neither hypovolaemia nor cardiac failure appears to be the cause, a fluid bolus of 200 mL intravenously should be administered. If this does not result in diuresis, measuring the central venous pressure will be beneficial. (Further fluid boluses may be harmful if the central venous pressure is high, and a diuretic challenge is contraindicated if the patient is hypovolaemic.)

Established renal dysfunction

Established renal dysfunction requires intensive monitoring of fluids and electrolyte balance. Transferring the patient to an intensive care or high-dependency environment becomes necessary, and the management of their renal dysfunction is primarily managed by the intensive care team. Fluid overload, hyperkalaemia and acidosis are the primary threats. The risk of upper gastrointestinal bleeding increases, and prophylactic proton pump inhibitors should be administered. Nephrotoxic drugs must be avoided. Urgent reduction of hyperkalaemia exceeding 6.5 mmol/L is essential. Conservative measures to lower potassium levels include correcting the acidosis, administering glucose and insulin infusions, using oral exchange resins, intravenous calcium administration, and high-dose frusemide. Renal replacement therapy is indicated for hypervolaemia and for hyperkalaemia or acidosis that do not respond to conservative treatment (persistent potassium concentration over 6.5 mmol/L or pH below 7.2). Various renal replacement techniques are available, but the most commonly used in the acute postoperative patient is continuous venovenous haemofiltration, with a pump providing flow through the system. In the postoperative patient, renal dysfunction is most often part of a multisystem failure, and the patient frequently requires cardiac inotropes and mechanical ventilatory support.

INTESTINAL COMPLICATIONS

Temporary intestinal failure following abdominal, and particularly gastrointestinal, surgery is common. An ileus typically resolves spontaneously and is rarely life threatening; however, more severe manifestations lead to severe malnutrition, which often goes unrecognised yet is a significant cause of increased mortality and morbidity in surgical patients.

INFECTIVE COMPLICATIONS

The diagnosis of sepsis during the postoperative period is not always straightforward. Pyrexia, along with an increase in WBC count or C-reactive protein, may occur as part of a systemic inflammatory response to sterile tissue damage. In some cases, overwhelming sepsis can lead to a decrease in WBCs and, especially in older people, the most apparent clinical features may present as cardiovascular decompensation, which is easily misdiagnosed as a primary cardiac complication.

During the first 48 hours after surgery, any infection is most likely related to the original septic pathology that necessitated the surgery or to a respiratory infection. Central line sepsis must also be considered. Dead tissue, whether from the gut or the soft tissue of an amputation stump, may present as ‘sepsis’. Evidence of sepsis occurring 7–14 days after any intra-abdominal anastomosis should raise the possibility of an anastomotic leak. This possibility must be excluded, as urgent re-exploration will often be necessary if a leak is discovered. Intra-abdominal, pelvic and wound abscesses may also present during this time, and respiratory, central line and urinary tract infections are additional possibilities. Antibiotic therapy alone is insufficient if there is necrotic tissue or extensive contamination with a collection of infected gastrointestinal contents. Dead tissue must be excised, and any pus must be drained.

MULTIORGAN FAILURE

Direct tissue injury, whether due to traumatic, surgical, thermal or infectious causes, releases chemicals from damaged cells into the circulation, triggering a systemic inflammatory response. The consequences include endothelial damage in capillaries throughout the body and subsequent harm to all organs. Furthermore, these damaged capillaries permit excessive fluid to escape from the circulation, resulting in profound hypovolaemia even in the absence of a bleeding wound or weeping burn. If aggressive fluid replacement is not initiated promptly, inadequate tissue perfusion and additional damage to vital tissues may occur. The cornerstone of management involves intensive physiological support, including inotropes, mechanical ventilation and haemofiltration. Nevertheless, the surgeon must remain vigilant for the possibility of an underlying surgically treatable pathology that requires intervention. An abdominal abscess, ischaemic bowel, or intraperitoneal or mediastinal leak from a gastrointestinal anastomosis is the most common scenario.

REHABILITATION

Healing of tissue at the surgical site continues after a patient has been discharged home. General weakness and fatigue following major surgery may take several months to resolve, especially if the surgery or the underlying condition was associated with sepsis or significant weight loss. Patients need guidance on returning to normal activities, as some unrealistically expect an immediate return to peak physical fitness, while others may hinder their full recovery by limiting their activities. Some patients might require specific dietary advice or a course of physiotherapy.

For some patients, returning to their preoperative level of health and lifestyle may not be possible. The physical and psychological adjustments to a prosthetic limb, a breast prosthesis or a stoma should not be underestimated. This requires careful patient counselling to manage expectations as part of informed consent. Other patients may need to adapt to a shortened life expectancy or a life with significant restrictions. When surgeons determine that they do not need to see a patient after hospital discharge, they must ensure that the patient has adequate professional or social support for continued recovery from surgery.

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4A Surgery of the skin and subcutaneous tissue

Shashank Lamba and Ebenezer Asirvatham

INTRODUCTION

The foundational step to mastering the techniques of surgery is to understand the nature of the integument. The skin is responsible for the security, and support, of the normal form and function of the human body. It provides joint suppleness, heel strength and fingertip sensation, as well as other functions according to the specific body part that it covers.

Every skin incision, or wound, leads to a scar. Scars are somewhat unpredictable and may affect both form and function. Unchecked burn scars can deform long bones, while a well-placed transverse scar on the neck may be well camouflaged. On one end of this spectrum is the barely visible, conforming scar resembling natural skin, while on the other end is the hard, red, thickened and elevated hypertrophic scar or keloid. This variable result may stem from non-modifiable properties, such as thick hyperpigmented scars seen in darker skin, or from certain parts of the body that scar badly, such as the pre-sternal area.[1] The surgical aim is to do as little harm as possible.

Whether in an emergency or an elective setting, the first repair should not complicate further reconstruction. In many parts of the world, the attending surgeon may well be tasked with handling some of these initial problems prior to definitive care. It is therefore necessary to have a clear understanding of the principles of handling the integument and of basic wound care.

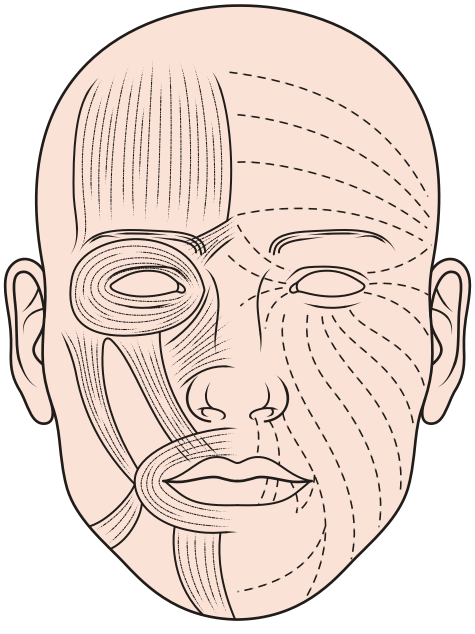
SKIN INCISIONS AND CLOSURES

INCISION PLANNING

The general principle is to place the incision on, or parallel to, the natural creases of the skin. In order to gain full access, the incision should be as close to, or over, the most prominent part of the pathology. This applies to the head, neck and trunk, while the flexural areas, extremities and joints are exceptions to this recommendation. Vertical incisions over the flexor aspects of joints may lead to contractures and, hence, curvilinear incisions should be used.

Relaxed skin tension lines (RSTLs) have been widely accepted (Figure 4A.1). Recently, biodynamic excisional skin tension (BEST) lines have been described in populations with high skin cancer rates. Paul (2018)[2] has provided a map of strategic incisions for access (Figures 4A.2 and 4A.3).

Evidence points to better healing along incisions placed parallel to the long axis in tubular structures such as the neck and extremities. For lesions in conspicuous areas such as the neck, incisions along the RSTLs may better disguise the scar, especially in dark skin with a tendency towards keloid scarring. The BEST lines for the non-exposed parts of the body may be used as recommended.



4A.1 Relaxed skin tension lines and the underlying facial muscles. ⏎

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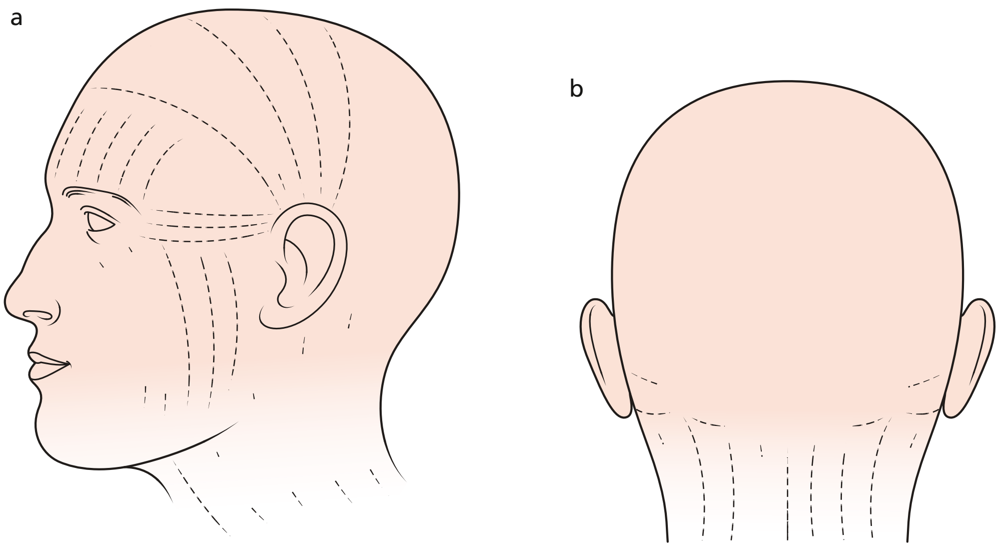
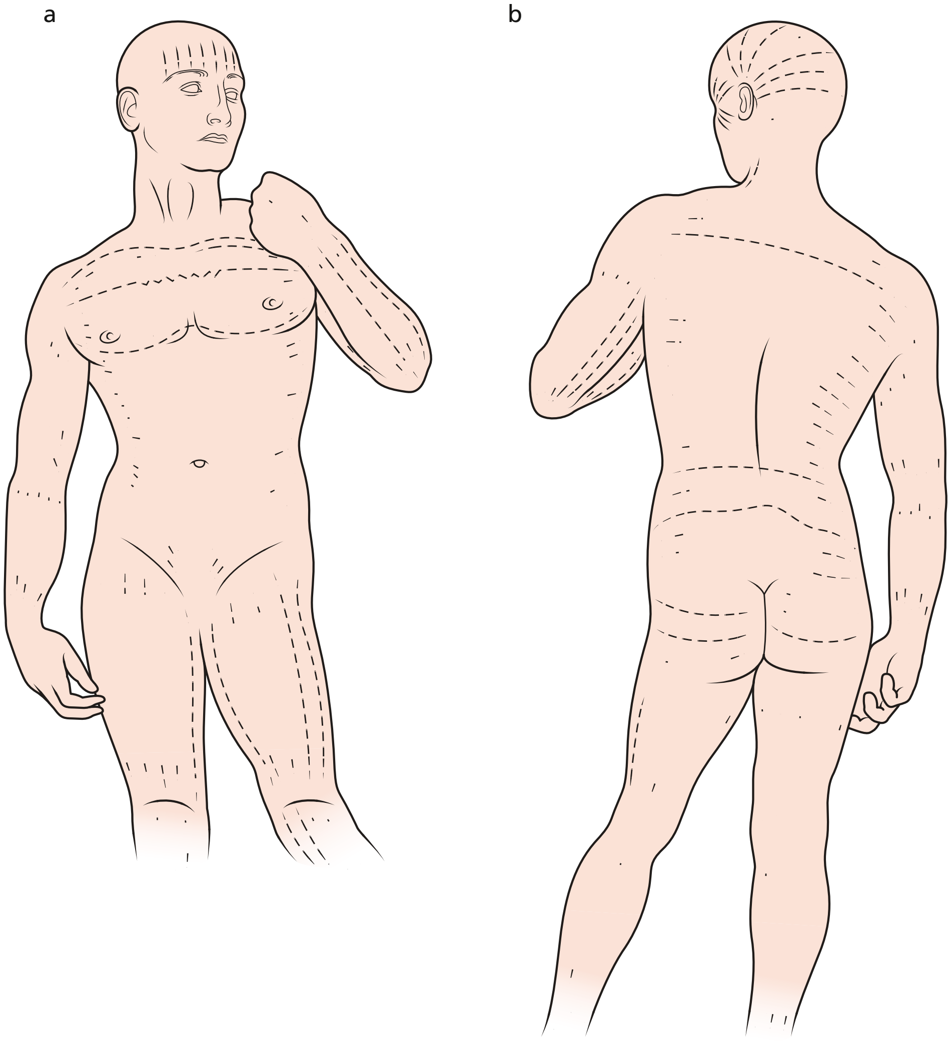


4A.2 Biodynamic excisional skin tension lines on the head. ⏎



4A.3 BEST lines on the trunk and extremities. (a) Anterior. (b) Posterior. ⏎

PERFORMING THE INCISION

Hold the scalpel ergonomically such that the cutting edge of the blade (size 15, 10 or 22) makes contact with the skin at an acute angle. The skin must be stretched taut for a clean incision. Alternatively, the use of monopolar diathermy on 'cut' mode for making an incision may be appropriate for thick skin, such as that of the trunk. Traction for thin tissue can be achieved with fine-toothed forceps and skin hooks. In areas with a rich blood supply, spend time to achieve haemostasis of the skin before proceeding. Otherwise, continued oozing from the dermal vessels may stain and obscure the deeper tissues, delaying progress. Bleeding from larger vessels in the subcutaneous tissue should be dealt with by bipolar cautery or ligated with a suture. One may encounter 'perforator' vessels[3] that pierce the deep fascia and supply the skin and subcutaneous tissues. Clamp-ligate or burn these perforators only if there is a limitation to complete access or bleeding due to vessel injury, as preservation of native blood supply leads to quicker healing. Keep the surgical field clean and do not cut blindly where visibility is limited.

CLOSURE OF SUPERFICIAL WOUNDS

Clean wounds

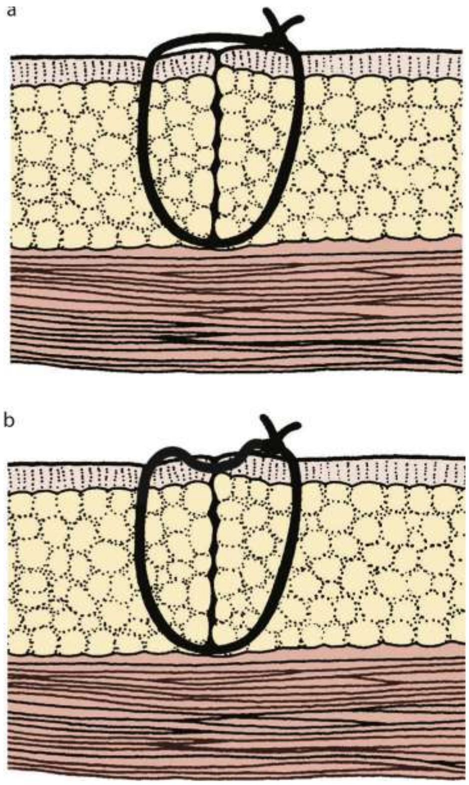
Evaluate the wound and decide if the goal is healing by primary intention. A severely contaminated wound is a contraindication to primary closure. Wound breakdown after primary closure can be minimised by following some precautions.[4] Firstly, convert a mildly contaminated wound to a clean wound by thorough debridement. Secondly, confirm that the skin flap and underlying subcutaneous tissue used for cover has a robust blood supply. Thirdly, obliterate any remaining dead space by 'quilting' stitches. A haematoma from unrecognised bleeding in a contaminated field could get infected, so take time to achieve haemostasis. Larger wounds that are contaminated or wounds that have been open for a considerable time may require a drain. Fourthly, do not close wounds under tension. Elective wounds with a large subcutaneous dead space that cannot be fully closed may lead to a collection, and vacuum drains may be placed deep to the skin.

Techniques for skin closure

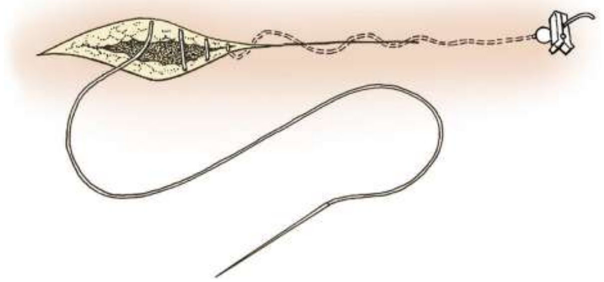
In general, the scar that unites the skin suture line regains 80% of the tensile strength of normal skin after 3 months.[5] Direct apposition of the skin edges with sutures is required until the scar achieves adequate strength to hold together independently. Layered closure of the subcutaneous fascia followed by skin closure yields the best results. Deep absorbable sutures that include both the fascia and the subcutaneous fat contribute to the strength of the wound.

In healthy patients, the face heals faster due to preferential blood supply. Facial sutures should be removed on the fifth day to reduce unsightly scars. Sutures on the skin of the rest of the body require at least a week prior to removal. Those on the back and lower legs may need to be left in place for 10–14 days. If wound healing may be delayed or there is any doubt about healing, retain sutures until needed. The obvious disadvantage is the epithelialisation of the suture tracts and the resulting scars from cross-hatching. The interrupted, evenly spaced, tension-free simple knot closure (Figure 4A.4a) may be the easiest and surest method recommended.[6]

Occasional vertical mattress sutures may be indicated to produce eversion of the skin edges (Figure 4A.4b). Once healed, inverted scars are hard to correct. Choose a delayed absorbable suture, such as polyglactin sodium (PDS), for deep subcutaneous closure and a monofilament nylon, or polypropylene, with a cutting needle for suturing the skin. As mentioned earlier, closure without tension and not crushing tissues avoids many of the healing problems,



4A.4 Simple and mattress sutures for closure. (a) A simple suture securing apposition of skin and underlying fat. (b) A vertical mattress suture. ⏎



4A.5 A subcuticular non-absorbable suture should be of a smooth material such as Prolene™ for easy removal, and the ends are brought out beyond the wound. If an absorbable suture is used, the ends are secured by buried knots. ⏎

although it takes some practice to master the 'just enough' tension surgical knot.

In elective clean wounds, the skin may be closed by a subcuticular dermal suture using a continuous 'running' synthetic absorbable monofilament suture material (Figure 4A.5). Alternatively, a running synthetic non-absorbable monofilament nylon stitch may be used if there are concerns about tissue reaction, with the suture ends secured on the outside and the suture removed at 10 days. Small superficial clean wounds can also be closed with Steri-Strips™ and tissue glue. Metal skin staples produce the worst kind of cross-hatched scarring. They should not be used if cosmesis is a concern and must be removed as early as possible.

SURGERY FOR SKIN LESIONS

BENIGN

Once a clear clinical diagnosis has been made, benign skin or subcutaneous lesions may be removed to establish the diagnosis, achieve better cosmesis or deal with complications such as pain, ulceration or bleeding. The surgeon must be well versed with the outcomes before operating. Excision biopsies may also be required to rule out malignancy. Disfiguring lesions such as birthmarks or malformations are best referred to the appropriate specialty.

LOCAL ANAESTHESIA

Consideration should be given to securing a patent peripheral intravenous line before an extensive procedure, rather than struggling with collapsed veins should an unexpected circulatory collapse occur.[7] Care must be taken to avoid inadvertent injection of large amounts of local anaesthetic into veins, for example in an axillary block.

Lidocaine is the preferred local anaesthetic for short procedures. Lidocaine is commercially available in 1% or 2% solutions (1 or 2 mg/100 mL) or combined with dilute adrenaline (1 in 200,000). The maximum recommended dose is 3 mg/kg. The two methods to increase the amount that can be injected are to either dilute the solution to 0.5% or combine the local anaesthetic with adrenaline, which causes local vasoconstriction and retains lidocaine longer in the subcutaneous tissue. The dose of lidocaine can be then be doubled to 7 mg/kg.

Injecting the solution can begin after the patient has provided consent and been counselled. Lidocaine is acidic and induces pain initially, followed by anaesthesia. To make the solution pH neutral, bicarbonate solution can be added, but this may cause precipitation. Prior application of local anaesthetic EMLA™ cream may reduce pain in an apprehensive patient and should always be used, if available, in children.

Introduce the needle and inject while withdrawing along the proposed incision line, followed by injection into deep tissues, in layers. Another method is to introduce the needle subdermally and progress forwards while injecting slowly. Estimate the amount of dissection required and infiltrate the surrounding tissues adequately.

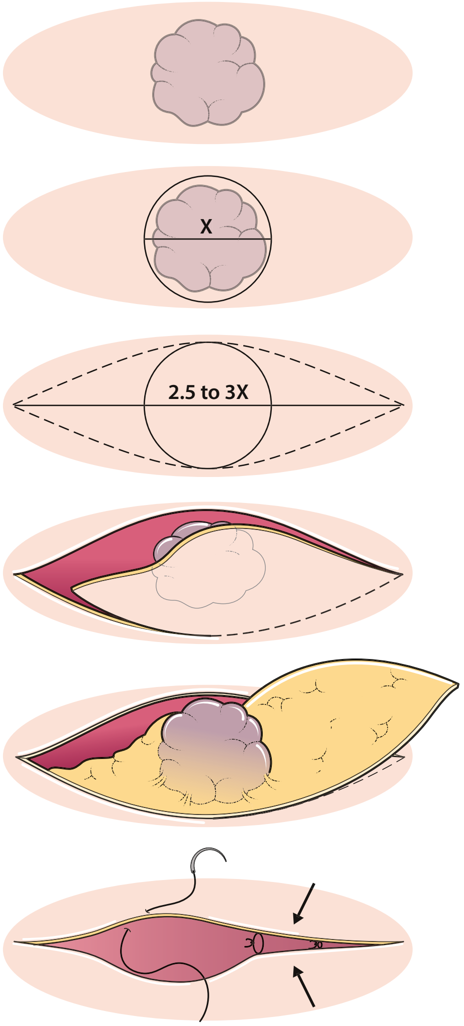
EXCISION OF A BENIGN LESION

Small skin incisions can be closed directly. If the intent is to close a wound primarily after lesion excision, the extent can be simply estimated by the 3X rule, provided that there is adequate lax surrounding skin (Figure 4A.6). Mark the outer border of the lesion and enclose it within a circle. The diameter of the circle forms the width 'X' of the excision. The incision line of 3X is marked on the long axis of the lesion, on the nearest skin tension line or parallel to it, as shown by McGregor.[8] The resulting wound will close without tension in a straight line.

Some lesions may be either left open for healing by secondary intention or skin grafted, depending on the case.

EXCISION OF A MALIGNANT OR POSSIBLY MALIGNANT LESION

It is important to distinguish between non-melanoma cancers (basal cell and squamous cell cancers) and malignant melanomas, as melanomas behave differently. The intended surgical goal for non-melanomas is curative excision.



4A.6 Primary closure of a defect by converting it into a straight-line scar along the skin tension lines. ⏎

Basal cell cancer (rodent ulcer)

Basal cell cancer (BCC) is the most common skin cancer and is noted for local destruction and high recurrence. The most common site is the face and other sun-exposed areas. If left unchecked, the tumour penetrates deeply. A biopsy may be necessary when there is doubt and the lesion cannot be easily excised. Current guidelines[9] have recommended surgery as the first-line option for primary tumours with excision margins of 4–6 mm, depending on risk. The prognosis depends on site, size, depth, subtype, invasion and negative margins. A completely excised primary lesion (on histology) has a recurrence rate of less than 0.5% at 5 years.

The surgeon should refer patients with BCCs in critical areas, such as on the nose, to a specialist. These include lesions close to the eyes, nose, ears and mouth that would require complete excision, preferably with excisional surgery and appropriate reconstruction.

Squamous cell cancer

Squamous cell cancer (SCC) may arise in skin with a high cumulative sunlight exposure and in chronic ulcers or unstable scars. Nodal spread is common and should be ruled out. Close cooperation with the dermatologist will facilitate correct staging, and it is important to identify lesions in less accessible areas such as the scalp, back or plantar regions. Full-thickness incisional biopsy may be done for planning management if the lesion is not easily amenable to excisional biopsy. Excision margins should be >4 mm for low-risk and >1 cm for high-risk lesions. In general surgical practice, the surgeon may deal with the primary SCC without nodal involvement. Locally advanced or higher stage tumours require imaging and individualised staged management in patients with confirmed nodal involvement. Such patients may be best referred to units with a specialist multidisciplinary team.

Malignant melanoma

Overall, malignant melanoma (MM) has the worst outcome and is the least predictable skin cancer. Patients with MM have the highest risk of local recurrence and metastasis. Prognosis depends predominantly on the depth of invasion or penetration, among other factors. The recommended excision margin is 1 cm for early melanomas of less than 1 mm in depth. A depth of 1–2 mm will require margins of 1–2 cm, depending on the site of the lesion on the body. Advanced cancer beyond 2 mm will require a larger margin of 2 cm and a defect down to, but not including, the next anatomical barrier, usually the deep fascia. Small suspicious lesions or a change in a pre-existing naevus should be excised with minimal margins rather than punch biopsied.

The unexpected diagnosis of MM may be made at microscopy by a pathologist in benign-appearing lesions. While disheartening, definitive wide margin clearance can still be performed after staging. Deeper spread requires staging of the draining nodal basin using the sentinel node technique. Following the Multicenter Selective Lymphadenectomy Trial (MSLT-I), sentinel node biopsy remains the most accurate method used for prognostication in intermediate melanomas. If positive, the patient should be considered for completion nodal dissection. MSLT-II showed that completion lymph node dissection improved local control but there was no difference in 5-year survival.[10]

MM spreads by both lymphatic and haematogenous routes and remains unpredictable. In confirmed cases, patients should be sent to an appropriate tertiary care centre, where available.

EXCISION OF A SEBACEOUS CYST

Any subcutaneous swelling may potentially be a sebaceous cyst. The characteristic punctum may not be found in all cases. Incomplete excision of the cyst, without confirming removal of the wall, will likely result in recurrence. Elective removal of sebaceous cysts of the back is better than in an emergency unexpected breakdown or abscess, especially in those with diabetes.

The 3X rule generally applies during excision. Depending on the site, stretched skin may be available in the scalp or extremities or may be lacking with a deeper plane, as in the back with thick skin. Planning is as outlined above, making an incision through skin alone, including the ellipse of skin that holds the punctum (Figure 4A.7). A clear plane may be difficult to find between the cyst wall and the skin. A balance must be found between retracting the skin edge and counter-traction on the wall to facilitate dissection. When a clear areolar plane exists, a 15 blade may be used. Alternatively, spreading and cutting with scissors, artery forceps or bipolar cautery may be needed, especially in recurrent cases. The cyst wall may rupture, spilling and contaminating the field. One can clamp the ends to continue to remove the wall, wash out the wound and close the skin. It may also be possible, in some cases, to electively rupture the distended cyst with an 11 blade, extract the contents and finish as above.

An infected sebaceous cyst with an abscess is best managed by incision, drainage and healing by secondary intention. Attempting removal of the inflamed cyst wall may result in ischaemic necrosis of the overlying skin. Aim to treat the abscess first, and remove the cyst wall in a separate sitting if the cyst recurs. On some occasions, abscess drainage can eradicate the cyst problems.

EXCISION OF A LIPOMA

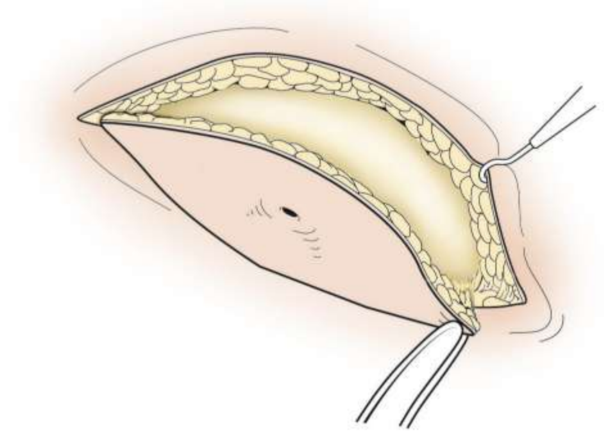
The majority of lipomas are solitary, although many attain a large size. A sudden increase in size or new onset pain should be taken seriously, as what was thought to be a lipoma could be either a sarcoma *de novo* or a sarcomatous change in a lipoma.

A facial lesion near bone fusion lines could be a dermoid and may require imaging. A scalp lipoma may 'disappear' after injecting local anaesthetic, confounding the surgeon. In such cases, it is likely that the lesion is in the subgaleal plane.

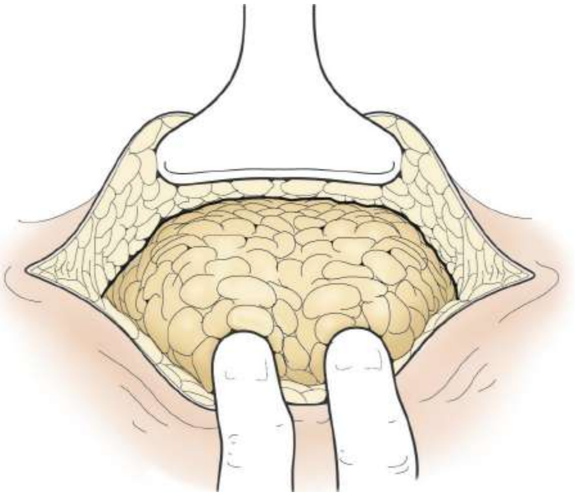
Multiple lipomas over the extremities may be extracted by small stab incisions, with the lipoma then shelled, or pressed, out. The lipoma may have a thin, inconsistent pseudocapsule. One can generally make out a difference in the size, orientation and arrangement of fat globules in a lipoma in comparison with the normal subcutaneous fat (Figure 4A.8). Large lipomas of the upper midline of the back may have extensions compressing, or enveloping, subcutaneous nerves and may require conversion to general anaesthesia or sedation.

SURGERY FOR SKIN LOSS

The surgeon encounters acute skin loss in a patient due to direct trauma, infection or burns. Patients with chronic wounds or ulcers caused by pressure and ischaemia may also be referred. A full-thickness



4A.7 Excision of a sebaceous cyst with its skin on the punctum. The artery forceps on the freed corner are useful for retraction as the lateral skin edge is lifted initially with a skin hook. ⏎



4A.8 Excision of a lipoma. Retraction, with counter-traction, demonstrates the fine strands of areolar tissue that are all that cross the plane between a lipoma and the surrounding fat. ⏎

circumferential thermal or chemical burn, also called an eschar, runs the risk of impending ischaemia of the limb or torso by external compression. Similar to a fasciotomy, escharotomy[11] requires a full-thickness linear incision down to viable tissue throughout the extent of the insensate eschar as soon as possible.

Early excision of deep partial- or full-thickness major burns within 72 hours, and grafting within 3 weeks, improves survival and reduces complications. These major burns are best managed by early referral to a tertiary care burn centre, if available.

NECROTISING INFECTIONS

Rapidly ascending cellulitis of the extremities often masks the extent of underlying dead tissue. When detected early, there may still be a chance that using high-dose parenteral antibiotics may avoid an extensive debridement. Sadly, most patients present late and have multiple comorbidities. Removal of the dead tissue may be the only way to prevent overwhelming sepsis. These patients almost always require critical care and have a prolonged hospital stay with multiple procedures.

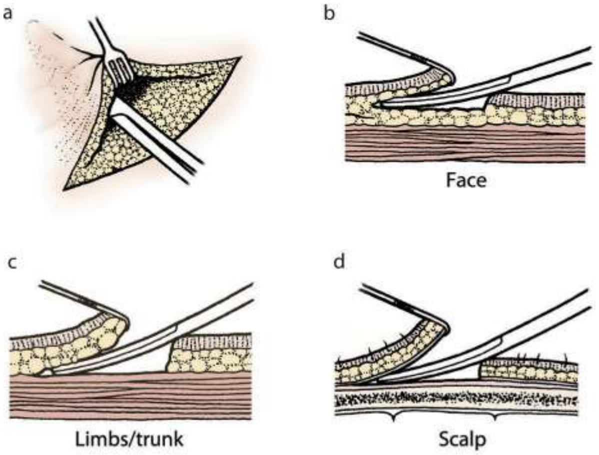
Necrotising fasciitis is recognised on the table by thrombosed perforator vessels deep to the fascia and liquefaction of the subcutaneous fat. The overlying skin does not bleed and will need to be excised until healthy bleeding tissue is reached. The aim is to excise all of the dead tissue to reduce the septic burden at the initial procedure. Rarely, a fasciotomy incision may relieve severe cellulitis and prevent impending necrosis. In most cases, it will take more than 2 weeks until the wound granulates adequately for subsequent skin grafting.

RECONSTRUCTIVE PROCEDURES

It may not be possible to close all wounds directly. Some loss of skin, whether anticipated or not, can be managed at the secondary care centre. Critical areas such as the head, neck, functional parts of the extremities, exposed vessels, bone and perineal wounds usually require specialist input and management if available.

ADVANCEMENT AND CLOSURE

Some wounds may be closed by undermining the surrounding tissue with tissue advancement for a tension-free direct closure (Figure 4A.9). This is more likely to be achievable in the lax skin of older patients. Any underlying vessels deep to the fascia should be preserved when undercutting and mobilisation.



4A.9 Undermining for direct closure. Undermining of skin edges can reduce tension on a suture line. The general technique is shown in (a). The optimum depth for this undermining varies in different parts of the body (b–d). ⏎

The scalp may be mobilised in the subgaleal plane and the face in the sub-superficial musculo-aponeurotic system (SMAS) plane and, for the rest of the body, mobilisation is below the deep fascia. Sometimes, large flaps can be advanced further by making galeal cuts perpendicular to the direction of advancement without injuring the underlying pedicle.

SKIN GRAFTING

Skin grafts provide biological cover and are a source for epithelialisation of the wound surface. Some prerequisites for the wound to be grafted must be met. Firstly, the recipient site must have a sufficiently vascularised bed. An elective wound has the best graft uptake. In other wounds, this is recognised by bright red granulation tissue. A well-established bridging technique is the use of vacuum-assisted closure until the wound is ready for grafting. Secondly, the open wound must be cultured to rule out beta-haemolytic streptococci group A. Colonisation by bacteria is inevitable, but can be controlled by frequent dressing.

In many societies, local antibiotic-impregnated dressings, locally debriding agents and vacuum-assisted closure may be too expensive or not widely available. Frequent dressing changes, with close attention to the wound, may result in better outcomes. Where accessible, the closed vacuum-assisted system accelerates healing when used in the appropriate patient.

A simple way to remember dressings is to consider the three-layered CAB dressing: **C** for contact, **A** for absorbent and **B** for binding. The contact layer is usually paraffin gauze to cover the wound, followed by the absorbent layer made of cotton pads and a layered bandage for binding.

At operation, the wound should be cleaned and excess granulation removed until the base is bleeding. Haemostasis must be achieved prior to placement of the graft. Clots and ongoing bleeding lift the graft and prevent adherence.

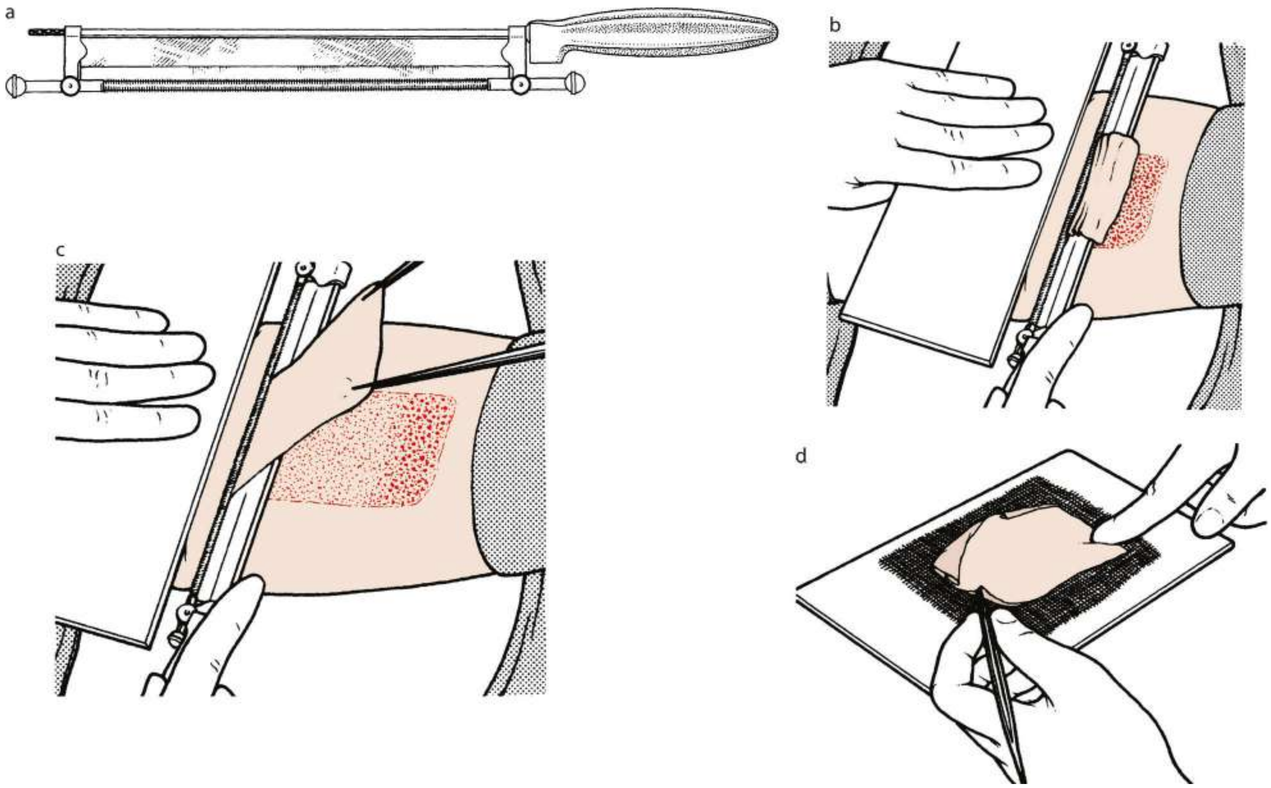
The donor site chosen for split-skin grafts must have hair follicles for re-epithelialisation of the site to occur. Otherwise, the donor site may progress to a full-thickness wound. Skin harvest requires at least two people. The assistant must stabilise the thigh and provide counter pressure from below such that the surgeon is presented with a near-flat or convex surface to take the graft. Another assistant may stretch skin flat on both ends using a wet gauze, or flat boards, along with paraffin as a lubricant. Set the handle of the dermatome with the grafting blade at the desired graduated thickness. The surgeon presses down with their non-dominant hand to create a narrow flat area and places the handle flat on the skin with the cutting edge making contact (Figure 4A.10).

Using a controlled ‘to-and-fro’ motion, the surgeon should ensure that, with the first few movements, the desired thickness has been obtained. Progress forwards steadily until sufficient skin graft is obtained.

Thin grafts are translucent and may have little upper white dermis on the underside. Thickness can also be estimated by pinpoint bleeding from the donor site dermis in thin grafts and larger bleeding points in thicker sections. If fat is encountered, the plane is full thickness. The handle should be taken out, checked and readjusted to start again. The donor site will have to be sutured. If all goes well, a layered adherent dressing should be left in place for 7–10 days for epithelialisation to occur.

Meshing of the graft can be done by hand on a flat board using a 15 blade. Alternatively, expansion can be performed in increasing ratios, from 1:1.5 to 1:6 using a mesher. The amount of meshing is inversely proportional to the cosmetic outcome. Scarring and secondary contracture in the intervening raw areas retain the meshed appearance thereafter.

Bridging techniques are employed in extensive burns, whereby large portions of the body may be temporarily covered with a biological membrane like an allograft. The collagen scaffold in the graft may be partially integrated into the wound and later rejected at 2 weeks. By this time, patient survival is likely and



4A.10 Skin grafting. (a) A skin grafting knife. (b) The method of cutting a split-skin graft. (c) The pattern of bleeding is an indication of the thickness of the graft that has been taken. (d) The graft is spread out on a tulle-gras dressing. ⏎

the patient's own meshed autograft will complete coverage of residual burn wounds.

Thin grafts can be stored without meshing and wrapped in antibiotic-impregnated tulle gras at 4°C in a refrigerator for 2 weeks. The grafts should not be frozen. Before application, the graft can be meshed.

FIXATION OF THE GRAFT

The graft must conform to the wound bed and be secured by sutures or staples. The two greatest obstacles to graft uptake are incomplete contact with the bed and post-procedural shearing. This may be from bubbles, serous fluid pockets or clots that lift the graft. A 'tie over' dressing should be used if one expects the patient will move and displace the graft. A paraffin-soaked gauze with damp cotton is placed over the graft and held down with silk ties to prevent shearing, or lifting, of the graft.

GRAFT CARE

The graft should be checked at 5 days in clean elective wounds. Otherwise, the dressing should be changed at 48–72 hours. Sometimes, the epidermis might separate but the white dermis may remain stuck to the bed. In this situation, the excess dead graft should be trimmed from beyond the wound edges. Graft uptake may be partial in some cases and one must decide whether regrafting is indicated.

FULL-THICKNESS GRAFTS

These grafts are mainly used in elective wounds created on the face or, less commonly, the fingers. Excision defects close to the eyelids, nose, ears or mouth that require colour match are the most common defects considered for full-thickness grafts. Full thickness should also be considered for traumatic defects and following the release of contractures of the fingers.

The preferred donor sites for these grafts are flexural areas such as the post-auricular area, cervical area or groin. Women also have additional donor sites from the inframammary crease. Before infiltration, the exact template should be marked, preferably within an ellipse, so that the donor defect can be closed primarily. The graft is taken without subcutaneous fat and fixed to the wound securely using a tie over. Graft take is assessed at 5 days or later.

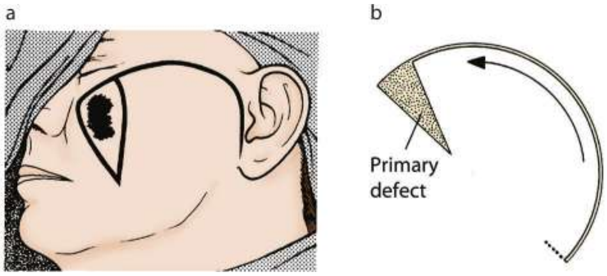
FLAPS

A flap is a section of tissue bearing its own blood supply. While flaps are traditionally used in the field of reconstructive surgery, surgeons have been using flap principles since the beginning of time. Flaps are more likely to survive in their entirety and do not depend on the recipient bed like an avascular graft.

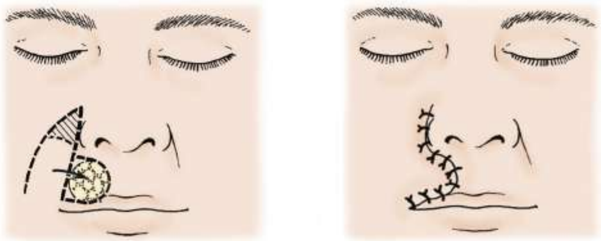
The surgeon might have to perform a local fascio-cutaneous flap on the face following skin cancer excision or a Limberg flap in pilonidal disease. A pedicled flap is mostly separated from the body but still has one intact portion with skin that contains its own blood supply. Islanded flaps are a further modification that are composed of an island of tissue, almost completely detached from the body except for the pedicle that provides its blood supply. More complex procedures such as the regional flap, with deeper structures such as muscle, require some guidance and specialist training.

LOCAL FLAPS

There are three basic types of local flaps based on their 'movement'. Local flaps can be moved by advancement, rotation (Figure 4A.11) or transposition (Figure 4A.12). The surgeon is more likely to succeed with a rotation flap raised in the gluteal region or for the cheek. Advancement flaps, such as a V to Y, are used for common fingertip injuries. When adequate skin is not available, such as in the scalp, a transposition flap with a width-to-length ratio of 2:1 can be raised. If there is a secondary donor raw area,



4A.11 A cheek rotation flap. (a) A large flap is necessary even when the defect is small. (b) A 'back cut' can be used to reduce tension. ⏎



4A.12 Transposition flap from a nasolabial fold to a defect in the upper lip. ⏎

it should be skin grafted. Local flap geometry and movement require further study.

The Z-plasty is a refined technique that uses two triangular flaps. They are cut at an angle of 60° and share one border, hence the 'Z'. The principle is that the procedure recruits and moves the surrounding excess skin roughly perpendicular to each of the triangular flaps and leaves the reoriented Z roughly perpendicular to the previous Z.

ADVANCED TECHNIQUES

Delay principle

Larger flaps may be prepared by using the delay principle. Each territory over the skin is supplied by a known blood vessel and separated by smaller 'choke' vessels that mark the boundaries. These smaller vessels can be 'recruited' by a surgical incision to include more skin in an area adjacent to the primary flap. In a week to 10 days, the vessels open up and the newly recruited tissues are included as an extension of the original flap.

Pedicled flaps

The injured hand with a skin defect may be covered by raising a pedicled flap from the opposite arm, abdomen, groin or thigh. After an interval of 3 weeks or more, for neovascularisation from the wound, the flap is divided and the hand is covered by the flap.

Free tissue transfer

Most major reconstruction is done by the use of free distant flaps, which are detached from the donor site after disconnecting the vascular pedicle and reattaching the blood vessels to vessels in the zone of the defect, or wound, using microscopic techniques.

Tissue expansion

A silicone balloon is placed in the subcutaneous plane and expanded incrementally until the desired amount of stretched skin is obtained. This expanded flap can be transferred as a local, pedicled flap or as a free flap.

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4B Surgery of the face and jaws

Shashank Lamba and Ebenezer Asirvatham

FACIAL WOUNDS

In some parts of the world, the attending general surgeon may well be called upon to manage facial injuries until patients with complex injuries are transferred to a tertiary care centre. It is important to spend time on the first procedure on a facial wound to optimise repair. Disfigurement could eventually lead to loss of both appearance and function.

DEBRIDEMENT

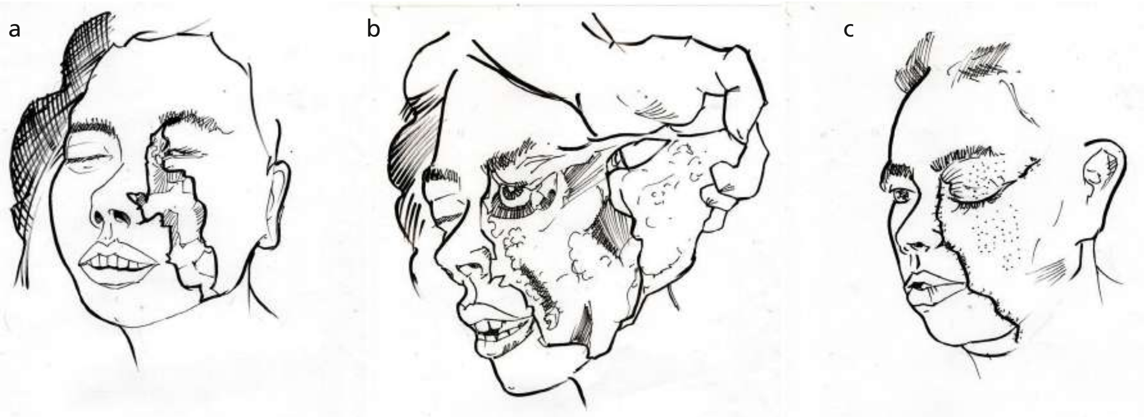
The face is a privileged site due to its proximity to the heart with an excellent blood supply. Contaminated facial wounds, when properly debrided, heal better than wounds in other areas of the body. Facial wounds may have all the components of a traumatic wound, such as lacerations, ongoing deep bleeding, degloving, burns, fractures and skin loss. Even when extensive, some parts can still be salvaged and injuries usually require early intervention (Figure 4B.1).

Most high-velocity facial trauma has a significant abrasive or burn component, as the head may be dragged along on the road or soil. Explore the wound and control the bleeding. Look for degloving and assess bleeding from the edges.

A ragged cut may be trimmed down to a clean, bleeding, viable line of closure, although not all ragged wounds need excision. One must be careful to preserve as much of the native skin as possible. Grains of embedded sand or other debris must be removed during the initial procedure. It may not be possible to remove all particles that are close to critical structures. Superficial abrasive burns to the skin are best managed conservatively.

WOUNDS INVOLVING CRITICAL STRUCTURES

Difficult facial injuries are best managed from the start by early referral to a tertiary care centre. When this option is not available, a well-done timely debridement, and closure, will protect these structures until definitive treatment is possible. Use landmarks to appose the pieces of the puzzle without excessive tension or undue distortion. An example would be



4B.1 Spend time on the initial debridement and closure of the facial wound. (a) Remove the contaminated tissues. (b) Look for key landmarks to appose. (c) Close and restore anatomy as best as possible. ⏎

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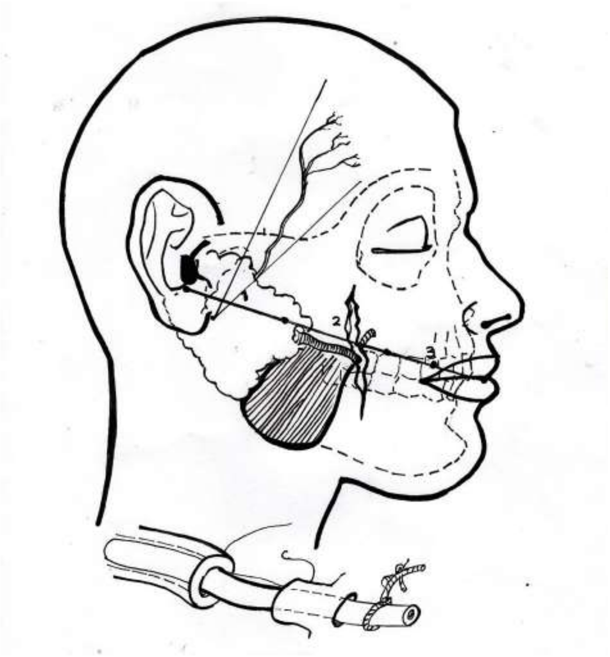


4B.2 Repairing the lacerated parotid duct over a stent. ⏎

aligning the vermilion border of the lip correctly to avoid a step deformity.[1]

Lacerations through the eyelid, nose, ears and mouth require a lot more attention than the rest of the face in order to restore the anatomy. While some tried and tested methods exist, one approach is to realign the more fibrous portions first, thereby providing adequate strength to the repair. Key trial sutures through the tarsal plate or the oral muscle, which may or may not be removed, are another method. Closure can then be performed, starting with the least-accessible area first, such as the internal mucosa of the lip, followed by the muscle and skin in separate layers. Injuries to the lacrimal duct, parotid duct (Figure 4B.2) and facial nerve are best managed via an early repair performed by a specialist.

Damage to branches of the facial nerve can occur before, or after, the terminal divisions of the nerve and are usually diagnosed clinically. The landmark is a line drawn perpendicularly to the plane of the lateral canthus. Major divisions lateral to this line should be repaired. The branching patterns medial to this line are miniscule and difficult to locate. They are best left undisturbed. Regeneration occurs through the extensive ramifications of the nerve distal to the site of injury.

A guideline to the course of Stensen's duct is the line drawn from the tragal border of the ear to the lip commissure. The opening may be anywhere in the middle third. The internal opening is found opposite the upper second molar.

Nerve and duct lacerations have better outcomes when repaired under the microscope. In some cases, grafts and stents may also be required, especially when staged repair is necessary. Most cases, although horrific at first, can be restored to a near-normal appearance with care and attention.

TISSUE LOSS

Reconstructive services must be involved as early as possible in cases of significant tissue loss, as the defect may progress as time passes and inflammation progresses. In general, most oral wounds with lost tissue can be bridged temporarily to promote primary healing without a raw area until definitive repair is possible. Scarring is much reduced when two epithelial margins, either skin or mucosa, are brought together.

In some cases, a thin split-skin graft may take well on abraded facial bones and skull, such as the maxillary prominence or the vertex. Burring the cortex may yield a sufficiently vascularised surface. Definitive flap cover, if indicated, should ideally be carried out as a separate procedure.

SUTURES

Fine sutures, such as 4/0 Monocryl with a round-bodied needle for the subcutaneous tissue or dermis, are likely to work as well as these sutures work in a clean wound. The skin can be closed with dyed 5/0 or 6/0 Prolene on a cutting needle.[1] Unless indicated, facial skin sutures must be removed on the fifth day to prevent unwanted scarring. However, the wound should ideally be splinted externally using adhesive tape for the next week.

FRACTURES OF THE FACIAL SKELETON AND JAWS

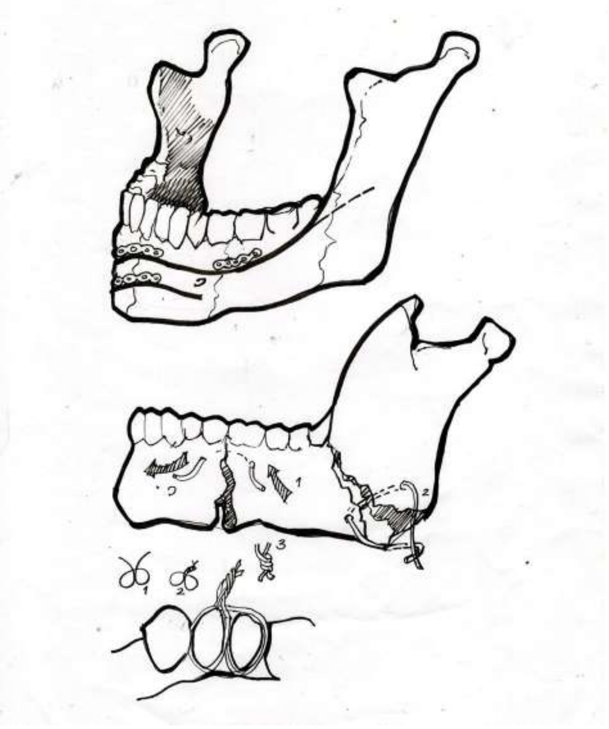
GUIDELINES

Management of these difficult problems requires some training in plastic or maxillofacial centres. In the event that the attending surgeon has no specialist training, some principles must be borne in mind.

Initial management of all major trauma follows the airway, breathing and circulation (ABC) pathway, with few exceptions. Most civilian falls, assaults and traffic accidents do not compromise the airway, despite the facial swelling. On the other hand, warfare injuries and gunshots may require an emergency tracheostomy. Some severe comminuted facial fractures may benefit from a temporary crico-thyroidotomy or submental intubation during fixation. Ideally, all craniofacial trauma should be evaluated with a computed tomography (CT) scan.

Facial fractures unite faster than fractures of the rest of the body. Splinting can be by internal fixation, external fixation or both. The principles of fixation are the same: to restore form (shape) and function. In some severe cases, form is likely to be sacrificed for function. For example, in comminuted pan-facial fractures with posterior displacement, occlusion takes priority over the restoration of normal facial projection.[2] The displacement of various structures also determines priority of fixation. A rare indication to intervene early, prior to fixation, is for decompressing severe orbital injuries. An emergency lateral canthotomy and cantholysis may be required in an impending orbital compartment syndrome.

Ideally, the fractures must first be exposed before deciding on the method and order of reduction. This could be from below upwards or in reverse. Another approach would be to focus on achieving occlusion first with arch bars and eyelets before internal fixation. In remote locations, this is probably the best approach for the surgeon. If proceeding with open fixation, one must strive to gain access to the normal or undisplaced segment. The unstable part is then fixed to the more stable structure.[3] A limited but practical approach is starting from the jaw and progressing upwards to the face.



4B.3 Mandibular fixation with wires and plates along the ideal lines. ⏎

FRACTURES OF THE MANDIBLE

Minor fractures may have a mobile or unstable dento-alveolar segment. Interdental wiring, by passing the wire between the teeth, can be performed with 26G stainless steel wire eyelets (Figure 4B.3). An arch bar cut to size can be used to hold the reduced fractures and also fix the mandible to the maxilla. Achieving normal occlusion is one of the primary aims of fracture reduction. Larger segmental fractures will require open reduction after achieving occlusion. It may be possible to manage some compound fractures by achieving reduction with rigid fixation, through the open wound, followed by mucosal and skin closure, although, in most cases, incisions have to be made along the gingiva-buccal sulcus for appropriate access. Rigid fixation entails the use of plates and screws, combined with wires, to restore occlusion, also called intermaxillary fixation. The fractures unite in 3 weeks, although most cases will require these wires to be retained for up to 6 weeks.

FRACTURES OF THE CHEEK BONES (MAXILLA AND ZYGOMA)

Maxillary fractures may present as part of the Le Fort midface fractures with comminution and displacement, depending on the vector. Minor fractures with a floating alveolar fracture may be amenable to temporary stabilisation with interdental wiring and a splint. A conscious patient might find temporary wire fixation a challenge to tolerate, even with multiple anaesthetic nerve blocks. Most cases require general anaesthesia for reduction.

Zygomatic fractures are commonly from a boxing injury. Clinical signs include a step deformity at the infraorbital rim and lateral displacement of the cheek. Orbital fractures typically present with a black eye. Entrapment of extraocular muscles in the trapdoor portion of an orbital blowout leads to double vision. This is a genuine emergency and must be released at the earliest opportunity. Trismus occurs due to impingement by fractured segments at the zygomatic arch and subsequent spasm of the masticator muscles. Objective evidence of fractures can be obtained with an occipito-mental view radiograph.

Isolated simple zygomatic arch fractures diagnosed early, with trismus and rotation or displacement, can be levered back into position using the minimally invasive Gillies approach. Access is obtained in the temporal scalp through a small transverse incision down to the temporalis muscle, deep to the deep temporal fascia. An elevator is passed through under the arch. Force is used to lift up the displaced bone, where the fulcrum is towards the surgeon. A click may be heard or rather felt by the operator. The attending surgeon must be familiar with the normal anatomical course of the branches of the facial nerve. Introduction of the elevator in the wrong plane may lead to both facial nerve injuries and bleeding from the pterygoid plexus. Improper technique with undue force can cause iatrogenic temporal bone fractures.

Nearly all other displaced zygomatic fractures have associated orbital injuries or other midface fractures and should be sent to a tertiary care centre, if possible.

NASAL BONE FRACTURES

The nose is probably the most commonly fractured area of the face. The nose is shaped like a tetrahedron. Injury to any of the walls, or the central septum, will lead to collapse of the tripod structure. Fractures can be caused by direct lateral or frontal force. The septum buckles or fractures in the majority and must always be inspected. A missed septal haematoma will lead to progressive septal fibrosis, resorption and collapse. Comminution varies and can be associated with naso-ethmoidal fractures.

The window of time to treat deformities is immediately or in the first few days before the fracture unites. Isolated fractures with lateral deviation may sometimes present early and respond favourably to simple reduction by external thumb pressure. When more than one of the walls are fractured or with delayed presentation, manipulation must be done under general anaesthesia. It is helpful to visualise the nose in the shape of an inverted W. A deviated nose occurs due to a deformed septum. All three walls must be straightened and restored to their original position.

The attending surgeon should use special instruments such as Walsham and Asch forceps. Protective rubber tubing should be placed on the blade that rests on the skin. Each of the lateral walls of the fracture must be grasped firmly and first gently displaced outwards, followed by moving the nasal bones back inwards to the desired position. This is similar to a door swinging on its hinges. The collapsed septum will need to be straightened by the blades of the forceps, which have a gap to avoid crushing the mucosa. Simultaneous finger manipulation may well provide the best reduction.

Nasal splinting is both internal and external, using a nasal pack for 48 hours and a strip of plaster of Paris for a week to retain the fractures in the reduced position. The external splint should be maintained at night for a further week.

SURGERY AROUND THE MOUTH

TRAUMA

A poorly carried out repair of a lip laceration will leave a very visible distortion at the vermilion border, even if it is minute. Layered closure should be done with absorbable sutures for the muscle and mucosa. A trial stitch to bring the muscle together may provide some orientation in ragged full-thickness lacerations. Begin closing from the mucosa and strive to align the vermilion border anteriorly.

Tongue lacerations bleed profusely when manipulated. The throat must be packed. Deep thick bites through the muscle with braided absorbable sutures produce the strength required for healing of the mobile tongue.

CONGENITAL CONDITIONS

Tongue tie

A tongue tie may be released by one of two methods. In newborns, the nearly avascular frenulum can be divided with a simple cut. In larger children, two haemostats may be used to clamp the frenulum immediately below the tongue. Either a monopolar cautery or a knife would suffice to cut through the frenulum. Interrupted absorbable sutures are placed. A Z-plasty may be required in some cases, being mindful of the opening of Wharton's duct.

Cleft lip and palate

Craniofacial clefts may be endemic with high incidence in certain populations. Other congenital conditions, in addition to cleft lip or palate, may increase risk during anaesthesia. These children require specialist multidisciplinary care and have excellent outcomes when referred early. Ideally, the surgeon must have some specialist experience before attempting any kind of repair, even in cleft lips.

Older children or adults with a cleft who live in remote areas present a dilemma for the surgeon, who may decide on improving the cosmetic outcome. Functional speech improvement may not always be possible.

MALIGNANT CONDITIONS OF THE FACE

Up to one-third of the length of the lower lip and a quarter of the upper lip can be excised as a wedge with primary layered closure.[4] The midline philtrum limits the cosmetic outcome of upper lip excision, accentuating asymmetry. While small excision biopsies can be planned along the tension lines, large or full-thickness excisions are better managed by a local flap.

Intraoral premalignant conditions such as leukoplakia of the buccal mucosa or small ulcers on the tongue could be part of field-change cancer and may best be referred for evaluation once a representative biopsy has been performed. The surgeon may see a locally advanced intraoral tumour in remote areas, which would necessitate resection and *en bloc* excision of the nodal drainage basins. These patients require major reconstruction, such as a pedicled pectoralis flap or free fibula grafting, and referral to a specialist centre should be expedited. Older methods such as combined forehead and scalp flaps are rarely performed as a salvage procedure, but may be considered in a resource-poor setting.

PECTORALIS MAJOR FLAP

The vascular basis of this flap is the secondary blood supply to the pectoralis from the thoracoacromial artery. A line is drawn from the xiphisternum to the acromion. A second line is drawn starting from the mid-clavicle, running perpendicular to where the first line ends. This marks the pedicle.[5] The required island of skin is incised and the muscle is cut through medially to expose the pedicle running deep to the muscle. Once identified, the amount of muscle to be included in the pedicled flap can be narrowed and modified (Figure 4B.4). The island can then be tunnelled subcutaneously to the cervico-facial region. If a deltopectoral flap is being planned, it must be elevated first before planning the pectoral island.

FOREHEAD FLAP

The forehead flap may be employed as a two-stage or single-stage procedure for resurfacing full-thickness cheek defects. Forehead flaps can be used with a scalp flap, which forms the external cover, while the forehead forms the lining.

Another staged variant is to pre-laminate the undersurface with a split-skin graft for buccal lining after partial elevation. After a sufficient period of delay, the flap is fully elevated and inserted into the defect. The next stage is division of the flap, returning the remaining flap to its original position.[6]

SURGERY AROUND THE EAR

TRAUMA

Sharp lacerations resulting in full-thickness tears to the auricle can be closed in layers after first securing the cartilage. Mattress absorbable sutures can be used to appose the cartilage. Some portion of the cartilage edges may be trimmed to make sure that the skin completely covers the cartilage. Avulsed earrings lead to a bifid earlobe. This defect is usually closed in layers and ear piercing can be carried out, preferably away from the healed scar, a few months later.

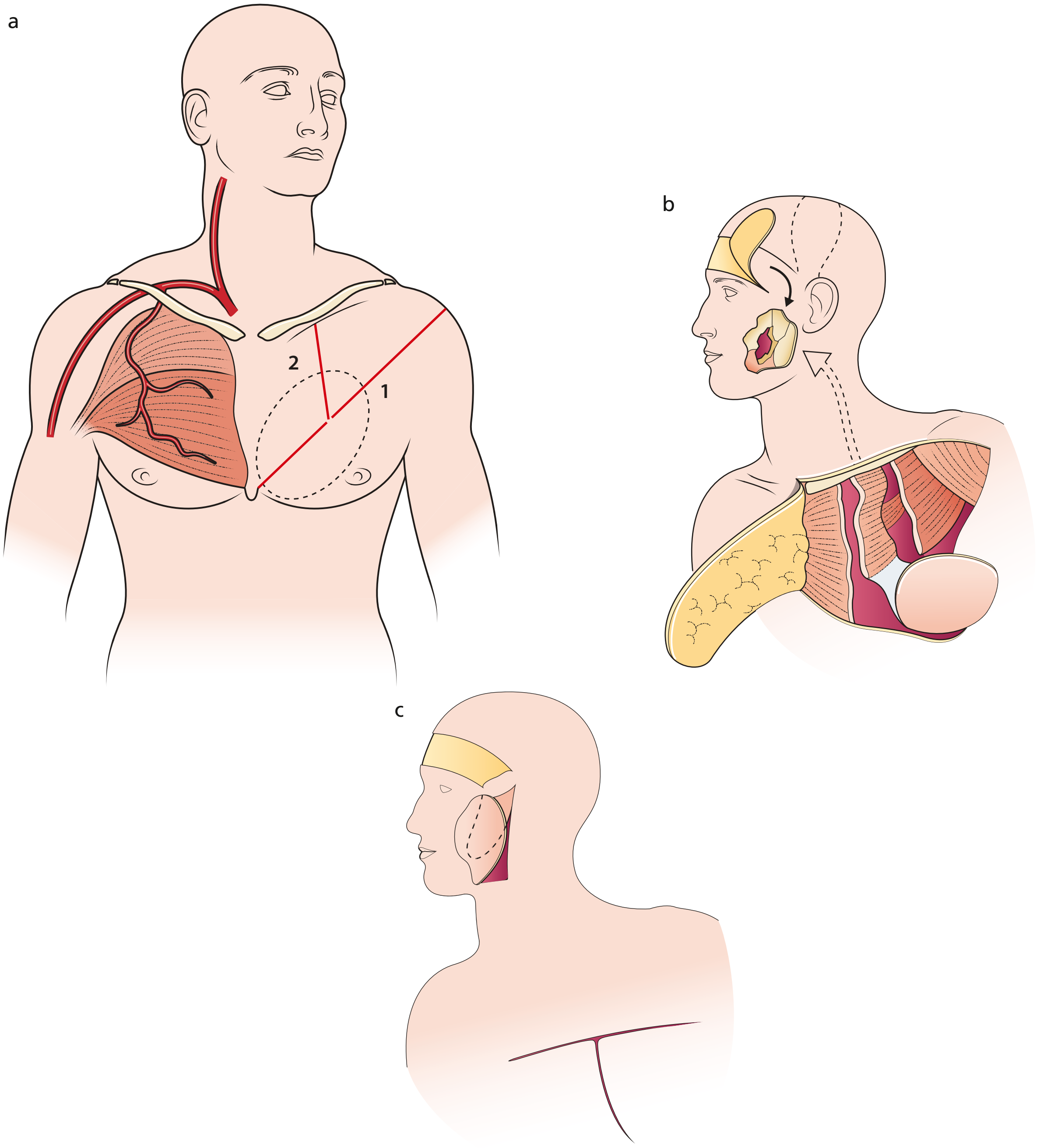
Blunt injuries may cause internal bleeding. Untreated haematomas cause pressure necrosis of the cartilage with internal scarring of the perichondrium. Progressive distortion of the normal architecture leads to the cauliflower ear deformity. The patient must be operated on under general anaesthesia due to severe pain on manipulation and the proximity of the vagal branches. Early clean incisions should be made over the haematoma, with drainage.[7] Pack the dead space with moist cotton over paraffin gauze and reinforce with a pressure dressing such as a mastoid dressing. It may be worthwhile doing a twice-daily dressing change to check if a clot has reformed. Compression from both sides, using moulded bolster mattress ties, prevents further bleeding.

Untreated superficial burns may lead to perichondritis. Twice-daily application of an antibiotic cream usually suffices.

Always examine the external auditory canal. Missed temporal bone fractures can present with blood accumulation in the external auditory meatus. A laceration close to an ear may turn a temporal bone fracture into a compound fracture. Ongoing bleeding from the canal may respond to adrenaline-soaked gauze. These patients may develop complications such as stenosis and should be seen as soon as possible by a specialist.

BENIGN LESIONS

Infected sebaceous cysts may present with pain but are rare. There may be no other choice but to excise a part of the cartilage in order to close primarily. Skin tags and accessory auricles with included cartilage can be excised along the crease lines with an ellipse. Ear keloids usually recur and deform the ear. They must be handled with care and generally require multimodality treatment.



4B.4 Pedicled flaps to cover a full-thickness defect of the cheek. (a) The pectoralis major myocutaneous flap markings along the axis of the thoracoacromial vessels. (b) The pectoralis major flap with forehead, scalp and deltopectoral flaps. (c) The completed inset and closure of the defect in two layers using two pedicled flaps and skin grafts. ⏎

MALIGNANCIES

Superficial lesions may be punch biopsied. It may be possible to retain a graftable bed by preserving the perichondrium. SCC and ulcerated lesions can seldom be removed without a wedge excision. The resulting V-shaped defect can be closed in layers with minimal distortion in most areas, except the root of the auricle. Large lesions are managed by local flaps, usually performed by a specialist.

INFECTIONS OF THE FACE

Surgical drainage of infections is seldom necessary when there is early access to antibiotic treatment. However, general surgeons practising in areas where many patients are remote from primary healthcare facilities may still have to operate for facial infections.

SOFT TISSUE INFECTIONS

These infections can occasionally lead to major tissue destruction. Cancrum oris, which is encountered almost exclusively in malnourished children in the developing world, is a spreading necrotising synergistic infection. Treatment is with penicillin and metronidazole, nutritional support and excision of necrotic tissue. The final full-thickness tissue loss, extending from the mouth into the cheek, will require skilled surgical reconstruction, but should ideally be deferred for 3–6 months. Sometimes, these children can be transferred to a regional plastic surgical centre or treated by a plastic surgical team on a short-term medical mission.[3] Unfortunately, this is a disease that occurs in the areas of the world that are least served by specialist care. A general surgeon unable to transfer a child might be able to improve the situation with one of the flaps described earlier in this chapter or even a waltzing flap.

INFECTION IN THE ORBIT

Orbital infection may be secondary to a sinus infection or a penetrating injury. Pus behind the eye is always under pressure, and the patient has severe pain, proptosis and some unilateral visual impairment. Pus can be drained by an incision in the sclera-tarsal fold. Pus within the orbit secondary to an ethmoid sinusitis is most satisfactorily drained by a Lynch–Howarth incision (see Figure 4B.7). An eye destroyed by pan-ophthalmitis and filled with pus must be enucleated or eviscerated (see ‘Ocular injury’ section later in the chapter).

SINUS INFECTIONS

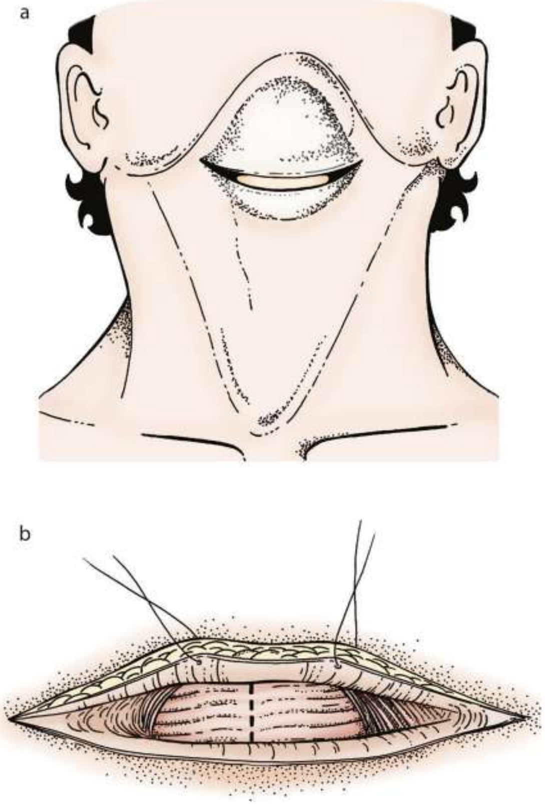
An infected sinus will occasionally fail to settle on antibiotic therapy. The sinus is filled with pus, which is unable to drain through an obstructed outlet, and surgical intervention becomes necessary. The maxillary sinus can be entered transnasally and washed out under local anaesthesia. A trocar is advanced through the bony lateral wall of the nasal cavity under the inferior turbinate, aiming for the tragus.

INFECTIONS OF DENTAL ORIGIN

Dental sepsis will commonly settle with antibiotic therapy, but if pus has formed then drainage is required. An alveolar abscess around the root of a tooth subsides rapidly after the offending tooth is extracted. A subperiosteal abscess may follow an untreated alveolar abscess. The pus may be on the external or internal surface of the bone and is drained into the mouth by an incision in the muco-periosteum parallel to the alveolar margin. Care must be taken in the region of the lower premolar teeth to avoid damage to the mental nerve. Ludwig’s angina is a bilateral cellulitis within the submental and submandibular triangles, associated with gross swelling. It is usually secondary to a dental infection. Drainage of pus or, more commonly, an incision simply to decompress the abscess may be necessary and a pre-emptive tracheostomy may have to be considered in such patients. Drainage of the submental space is shown in Figure 4B.5.

OSTEOMYELITIS OF THE JAWS

Osteomyelitis of the maxilla or mandible is extremely rare in patients who have access to antibiotic treatment for the primary dental or sinus infection. Drainage of



4B.5 Pus in the submental space may be deep to the mylohyoid muscle. (a) The transverse skin incision. (b) The vertical incision in mylohyoid. ⏎

pus from the bone or removal of sequestra will leave less scarring if it is possible to approach the disease from within the mouth.

PERITONSILLAR ABSCESS (QUINSY)

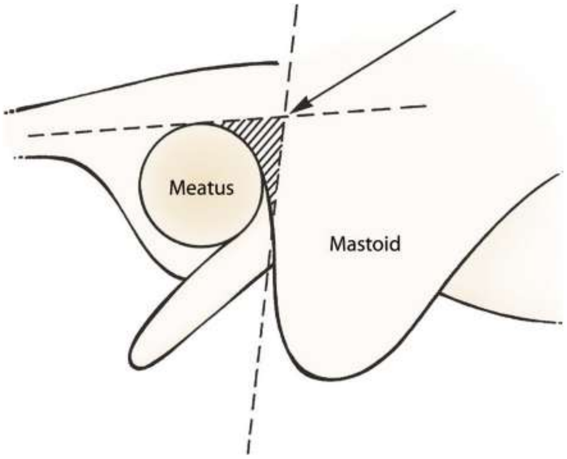
A peritonsillar abscess requires drainage of pus by an incision over the most prominent part of the swelling (under local anaesthesia in adults). The swelling is first aspirated with a needle to confirm the presence of pus. A mucosal incision is then made, followed by gentle exploration of the abscess cavity with sinus forceps. Any deep incision with a scalpel can result in torrential haemorrhage.

RETROPHARYNGEAL ABSCESS

A retropharyngeal abscess lies between the pharynx and the vertebral column, in the retropharyngeal space, which extends from the base of the skull to the posterior mediastinum. The abscess is visible as a bulging of the posterior oropharynx. In childhood, this abscess is seldom tuberculous and can be drained through the mouth; airway protection from inhalation is crucial. A tuberculous retropharyngeal abscess in an adult, secondary to cervical tuberculosis, is better approached from the neck.

ACUTE MASTOIDITIS

An acute mastoid infection that fails to resolve on antibiotic therapy will still occasionally require emergency drainage of pus from the mastoid cavity in order to prevent intracranial extension of the infection. A post-auricular incision is made 2 cm behind the post-aural crease, directly onto the bone of the mastoid. The periosteum of the mastoid is elevated until the anterior edge of the mastoid and the superior wall of the external meatus are seen. Imaginary tangents are drawn from these landmarks and they intersect on the mastoid. The area bounded by these tangents and the external meatus is called MacEwen's triangle (Figure 4B.6). Entry into the mastoid should be through this triangle to minimise danger to the facial nerve and the dura. Entry through the bone can be by drill or by chisel. A general surgeon forced to operate on this condition can be content with the release of pus and the placement of a drain for up to 48 hours. Further exploration of the mastoid cavity, the underlying dura or a thrombosed sigmoid sinus is likely to cause more harm than good.



4B.6 MacEwen's triangle. The periosteum is elevated from the bone until the anterior border of the mastoid and superior wall of the meatus can be identified as landmarks. A horizontal tangent, from the superior border of the meatus and continuous with the zygomatic arch, meets a vertical tangent, taken from the anterior border of the mastoid, to delineate the shaded triangle through which the mastoid cavity can be most safely approached. ⏎

SURGERY AROUND THE EYE

PERIORBITAL SKIN LESIONS

Removal of a skin lesion from immediately below the lower lid, followed by primary closure, can drag the lower lid down and cause it to be lifted away from the eyeball and even to evert (Figure 4B.7). This ectropion will result in a watering eye as the inferior punctum is no longer in contact with the eye. This situation can be avoided by a full-thickness graft. Direct damage can also occur to the nasolacrimal apparatus at the inner canthus. Periorbital skin lesions should be carefully assessed preoperatively, and referral to an ophthalmologist or a plastic surgeon for the initial operation should always be considered.

EXTERNAL ANGULAR DERMOIDS

These are congenital cystic swellings, usually at the superolateral margins of the orbit, which enlarge with age. They most often present in early to mid-childhood. Excision is normally straightforward, but they may be deeply indented into the outer table of the skull. The occasional dermoid has no bony separation from the dura, something that a surgeon would wish to be aware of prior to operation. It is therefore recommended that dermoids that feel fixed to the bone and dermoids that extend under the supraorbital ridge are examined by preoperative ultrasound, where possible, or, alternatively, an X-ray to confirm an intact inner table of skull. Complete removal of the intact cyst is important because, if ruptured during the surgery, postoperative inflammation can be intense. The incision should be just below, or occasionally above, and parallel to the eyebrow (Figure 4B.8). The temptation to hide the incision within an eyebrow is mistaken, as hair follicle scarring results in deformity of the eyebrow.

SURGERY OF THE EYELIDS

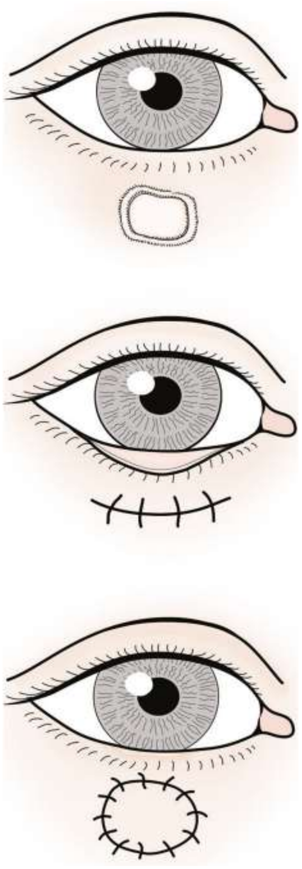
This fine surgery should normally be performed by either an ophthalmologist or a plastic surgeon. However, some general surgeons in remote environments may be able to offer some simple but effective surgery that can preserve sight in the underlying eye.

Eyelid repair

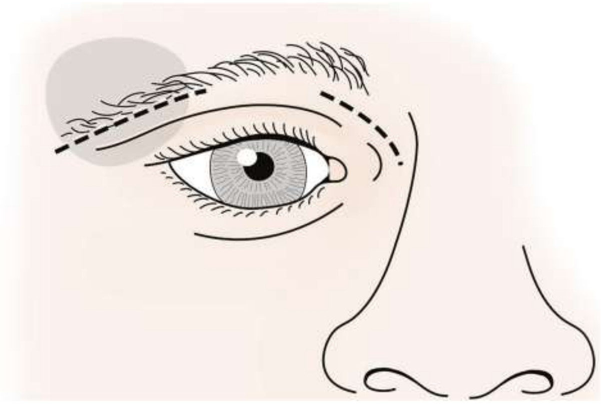
Lid repair after trauma can be successfully achieved by following general principles of accurate apposition of fine tissues, with particular care taken to achieve accuracy at the lid margins. The junction between the eyelid skin and the tarsal conjunctiva (the grey line) should be identified and sutured very accurately to avoid a step in the eyelid margin. The tarsal plate is repaired with fine, absorbable sutures, such as 6/0 Vicryl™, placed so that the knots do not irritate the cornea. The skin is then closed with fine, non-absorbable sutures. If, however, a canaliculus is lacerated, repair will be very difficult without the magnification of an operating microscope. When damage is suspected, it is confirmed with a lacrimal probe and repair is performed around a fine silicone tube passed through the lid punctum, across the divided area in the laceration and on through the distal duct into the nasal cavity. The silicone tube is left *in situ* for 3–6 months.

Tarsorrhaphy

Tarsorrhaphy is a simple temporary manoeuvre to save an eye. It is undertaken in a situation when the eyelid does not close over the eye during blinking and in sleep, which would result in drying of and trauma to the cornea, with impairment of sight. The underlying pathology may be a facial nerve paralysis, a severe proptosis secondary to hyperthyroidism or periorbital tissue damage from burns or other trauma. In these circumstances, a lateral third tarsorrhaphy will usually suffice, whereas a complete tarsorrhaphy may be required to protect an injured eye during healing. Fine plastic tubes are sutured externally along the whole or



4B.7 A skin tumour beneath the eye can distort the lower lid if it is excised as an ellipse and closed as a linear wound. A circular excision and a Wolfe graft produce a more satisfactory result. ⏎



4B.8 An external angular dermoid is often a deeper lesion than originally appreciated, and excision must be carefully planned to avoid scarring of the lateral eyebrow. The medial (Lynch–Howarth) incision is suitable for the drainage of orbital pus secondary to an ethmoid sinusitis. ⏎

the lateral thirds of the upper and lower lids. A loop of suture material is then passed through the two tubes, which, when tightened, draws the lids together with an even pressure. This technique allows simple painless opening of the lids to examine the eye. A more permanent lateral tarsorrhaphy can be performed by making an incision along the lid margin, between the eyelashes and the openings of the meibomian glands, to create a raw surface, before sewing the upper and lower lids together. However, other definitive solutions may be preferable. For example, a patient with a facial nerve palsy may be better served in the long term by the insertion of a gold weight in the upper lid, combined with a procedure to support the lower lid.

Ectropion and entropion

Ectropion may simply be the result of senile involution, but when it occurs secondary to infraorbital scarring the deformity can be corrected by release of the scar tissue followed by full-thickness skin grafting.

Entropion may also occur with senile involution, but in areas of the world where trachoma is endemic it is commonly secondary to conjunctival scarring from this infection. The inverted eyelashes traumatise the cornea. Any infection is first eradicated, after which the entropion can be corrected by excision of the scarred conjunctiva and replacement with a free full-thickness mucosal graft from the mouth. It may also be necessary to divide, and evert, a deformed in-turned tarsal plate. An alternative simpler strategy is radical excision of the in-turned eyelashes without attempting to correct the underlying deformity of the lid. Everting sutures, which pass through the skin, tarsal plate and tarsal conjunctiva, may be a simple procedure that produces temporary relief of the entropion.

Tumours of the eyelid

Tumours that involve less than one-quarter of the length of a lid can be excised as a full-thickness wedge, followed by reconstitution of the eyelid.

SURGERY WITHIN THE ORBIT AND OF THE EYEBALL

This is an area where a general surgeon without specific training has little to offer. The drainage of intraorbital pus is described above. Some surgeons may wish to train to be able to offer cataract surgery in remote areas, but most other intraorbital and intraocular procedures will be impractical for a surgeon with no training or experience.

Ocular injury

Ocular injuries can seldom be managed successfully by a generalist. The internal structures may have been disrupted by blunt trauma or the orbit may have been penetrated. A ruptured or lacerated eye should be sutured promptly to prevent loss of contents and collapse, which will further disrupt the internal structures.[7] If iris tissue is prolapsing through a corneal laceration, this tissue should be excised. However, an eye injury, especially one where the uveal tract is involved (iris, ciliary body and choroid), may occasionally induce a sympathetic ophthalmia in the contralateral eye, with loss of sight in this eye as well. The risk of this rare but devastating complication is reduced by early removal of an injured eye. Therefore, if an eye is severely injured and sight already irretrievably lost, procrastination over its removal may be harmful. Exposure of the posterior sclera is essential when a ruptured globe is suspected, as many ruptures start, or extend, posteriorly. A 360° conjunctival incision is made at the limbus (just outside the corneal–scleral junction) and all four quadrants of the sclera are exposed. A rectus muscle may have to be temporarily detached for access, but is later reattached with 6/0 absorbable sutures. A scleral wound is sutured with fine interrupted monofilament sutures and the conjunctiva reattached at the limbus with fine, absorbable sutures.

Enucleation

Enucleation of an eye is indicated for an intraocular malignancy and is also an alternative to evisceration for an eye destroyed by infection or trauma. The conjunctiva is incised at its junction with the cornea and the plane developed around the eyeball. Each intrinsic muscle is hooked forwards and detached from the globe. One stump should be cut long enough for artery forceps to be attached for retraction. Finally, the optic nerve is divided, the eye is removed and the conjunctiva is closed.

Evisceration

Evisceration is a more common procedure in which only the contents of the globe are removed. It allows a better cosmetic result, as there is some movement of the residual tissue. The cornea is excised and the contents curetted. All uveal tissue must be removed otherwise the patient is still at risk of sympathetic ophthalmia. In the absence of infection, four radial scleral incisions, towards the optic nerve and avoiding the extraocular muscles, create flaps that can be sewn together to form a central piece of tissue over which the conjunctiva can be closed.

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Surgery of the breast and axilla

5

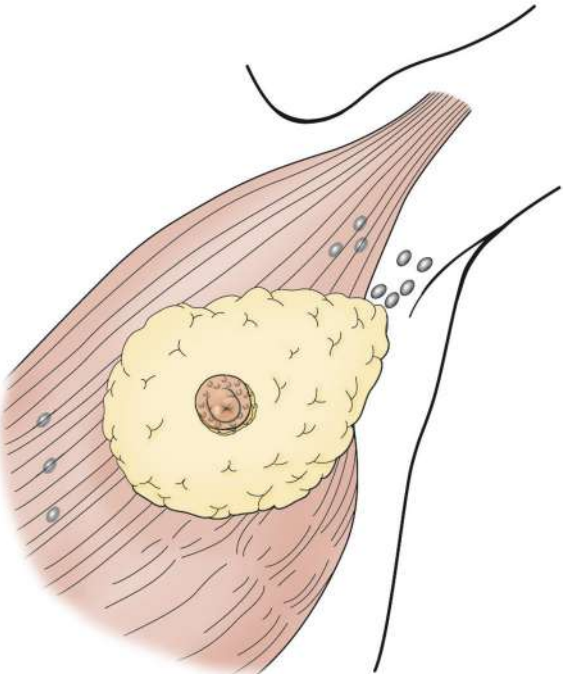
Paul Mazhuvanchary Jacob and Shawn Sam Thomas

SURGICAL ANATOMY

THE BREAST

The adult female breast lies on the anterior thoracic wall and extends from the second rib above to the sixth rib below and is composed of skin, subcutaneous tissues, breast lobules and ducts. Two-thirds of the breast lies on the pectoralis muscle and the rest on the serratus anterior muscle inferolaterally. Medially, it extends almost to the midline and superolaterally the breast may continue into the axilla around the lateral border of the pectoralis muscle as the *axillary tail of Spence*.[1] Superficially, the breast is separated from the skin by subcutaneous fat, except over the areola and the nipple. The nipple is usually situated at the level of the fourth intercostal space in nulliparous women; however, the position is inconsistent in pendulous breasts. The suspensory Cooper's ligaments are hypocellular septa running from the skin inwards to the pectoralis fascia and are responsible for holding the breast in the appropriate position. Infiltration of these ligaments results in retraction of the skin overlying the tumour.[2] The majority of breast tissue volume is in the upper outer quadrant and hence this is the most common site for occurrence of breast cancers. Alterations in hormonal levels cause structural and functional changes in the breast during pregnancy and lactation and, to a lesser extent, throughout the menstrual cycle.

The arterial supply for the breast is mainly from an anastomotic plexus formed by the internal thoracic artery and intercostal arteries. The internal thoracic artery sends branches along the first, second, third and fourth intercostal spaces that pierce the intercostal muscles. The vessel in the second space is the largest of these and plays a significant role in maintaining vascularity of the flap in patients having a mastectomy.[1] The deep surface of the breast is supplied medially by branches of the intercostal arteries and laterally by branches of the lateral thoracic artery. The venous drainage is either via the superficial system entitled the venous plexus of Haller, which follows the path of the areola under the nipple areola complex, or by the deep venous system. The lymphatic drainage is also via a superficial system, subareolar plexus of Sappey and deep lymphatic system.[3] The lymphatic drainage is 85% to the axillary lymph nodes and 15% to the internal thoracic nodes (Figure 5.1). The breast is supplied by the first to sixth intercostal nerves and a supraclavicular branch of the superficial cervical plexus.[3]



5.1 Diagram of the left breast. The breast lies on the fascia of the pectoralis major except for the axillary tail, which extends beyond the lateral edge of the muscle into the axilla. The lymphatic drainage is to the axillary and internal thoracic (mammary) nodes. ⏎

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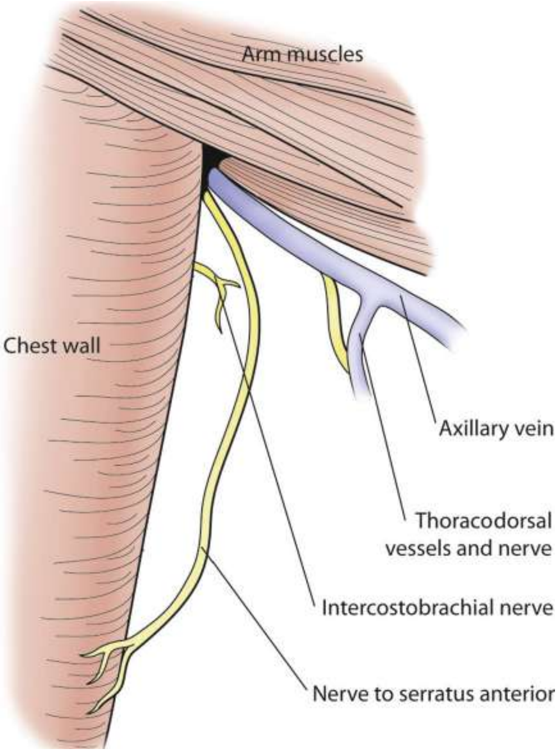
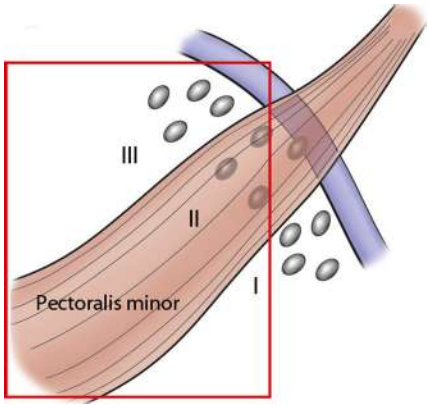


5.2 The axillary vein is the superolateral limit of an axillary dissection. The thoracodorsal vessels and nerve are preserved on the posterior wall. The intercostobrachial nerve (shown divided) and the nerve to the serratus anterior are encountered on the medial wall. The medial and lateral pectoral nerves, which cross the apex of the axilla, and the medial cutaneous nerve of the arm, running below and parallel to the vein, are not shown. ⏎

THE AXILLA

The axillary contents are the fat and lymph nodes bounded by the axillary walls. The medial wall is bounded by the chest wall covered by the serratus anterior muscle. The anterior wall of the axilla is formed by the pectoral muscles and the clavipectoral fascia. The posterior wall comprises the latissimus dorsi, teres major and subscapularis muscles. The axillary vessels and the brachial plexus lie along the narrow superolateral wall of the axilla. The axillary vein is the superolateral boundary of an axillary dissection. The axillary artery, with the brachial plexus around it, is superolateral to the vein and is thus safe and out of sight during an axillary dissection. Some branches of the plexus, however, will be encountered (Figure 5.2).

The thoracodorsal nerve (the nerve to the latissimus dorsi) and the thoracodorsal artery (a terminal branch of the subscapular artery) lie on the surface of the posterior wall and the nerve to the serratus anterior lies on the medial wall; they should be identified and preserved. The nerves to the pectoral muscles cross the apex of the axilla, and the medial cutaneous



5.3 Pectoralis minor is the landmark used to divide the lymph nodes into level I (below and lateral), level II (behind) and level III (above and medial) to the muscle. ⏎

nerve of the arm runs parallel and inferomedial to the axillary vein. The intercostobrachial nerves cross the axilla from the medial to the lateral.

The axillary lymph nodes lie in the fat of the axilla and receive lymphatic drainage from the upper limb and the superficial tissue of the chest wall in addition to the breast. Lymphatic channels from the breast predominantly drain firstly to one or more sentinel nodes, usually low in the axilla, and then subsequently to the higher nodes and finally through the apex of the axilla to the supraclavicular nodes. The axillary nodes are arbitrarily divided into levels I, II and III dependent on their relationship to the pectoralis minor muscle (Figure 5.3). Level I nodes are lateral and below the muscle and are formed by three groups: external mammary, axillary vein and scapular lymph nodes. Level II nodes are behind the pectoralis minor muscle and are formed by the central group and a few subclavian nodes. Level III are above and medial to the muscle and are formed by the subclavicular nodes. Lymphatics from the medial side of the breast pierce the pectoralis major and intercostal muscles medially to reach the internal thoracic nodes. Rotter's node (interpectoral) may drain directly into the central or subclavicular nodes and are potential routes for skip metastasis from the breast directly to level III nodes without the involvement of level I and II nodes.[1]

SURGICAL MANAGEMENT OF BENIGN BREAST LUMPS

Improvements in diagnostic facilities, combined with a greater understanding of the normal cyclical changes within the breast, have reduced the number of benign breast lump excisions. Many nodular areas can be safely left *in situ*. A solid, discrete breast lump that is believed to be benign on all assessment criteria may be left, but some patients and surgeons prefer excision because of the small risk of a missed malignancy. Inevitably, surgeons who do not have access to reliable mammographic or cytological diagnostic facilities will have to excise more clinically benign lumps. Large fibroadenomas – described as 'giant fibroadenomas' when over 5 cm in diameter – occur in young women. The resultant breast asymmetry and distortion will usually necessitate an excision for cosmetic reasons. Phyllodes tumours are found mainly in an older age group than women with fibroadenomas. Local recurrence after excision is common, and a wide local excision (WLE) of a phyllodes tumour with a margin of normal tissue is therefore recommended. Most are benign, 20% are borderline and the other 20% may be malignant. Borderline phyllodes tumours most often behave similarly to benign phyllodes. Malignant phyllodes can metastasise via the haematogenous route but lymph node metastases are not a feature.

Children in early puberty are sometimes referred to a surgeon with a tender lump deep to one nipple. This is a normal developing breast bud, and one breast frequently starts developing a few months ahead of the other. Excision is a disaster in a girl, as she loses all potential breast tissue on that side. Later in puberty, a girl may be concerned by enlargement of ectopic breast tissue, most commonly in the axilla. Reassurance may be all that is required, but excision is indicated if it is unsightly. Boys also frequently present with tender developing breast buds at puberty and reassurance usually suffices. In some boys, however, development continues – often on one side and then the other – until there is a small breast protrusion, which causes considerable embarrassment. Regression usually occurs after a year or two, but embarrassment is often such that surgical excision is justified.

BREAST LUMP EXCISION

Breast lump excisions can be divided into local excisions and WLEs:

- *Local excisions* include only the lump itself. This is a suitable technique for the removal of benign breast pathology.
- *WLEs* include the lesion with a margin of macroscopically normal breast tissue. This has increasingly become the preferred surgical management in proven, and occasionally in suspected, early breast cancer or as an option in locally advanced breast cancers post-neoadjuvant chemotherapy and also for phyllodes tumours. When an impalpable malignant lesion has to be excised, some method of marking the area must first be undertaken. Similar stereotactic and ultrasound methods can be used as for core biopsy, and this can be done in the breast imaging suite under local anaesthesia prior to surgery. A wire is inserted percutaneously into the centre of the lesion. At excision, the volume of tissue to be removed around the tip of the wire is judged by the extent of the lesion on preoperative imaging. After excision, the excised tissue should be X-rayed to check that the specimen removed incorporates the radiologically suspicious area.

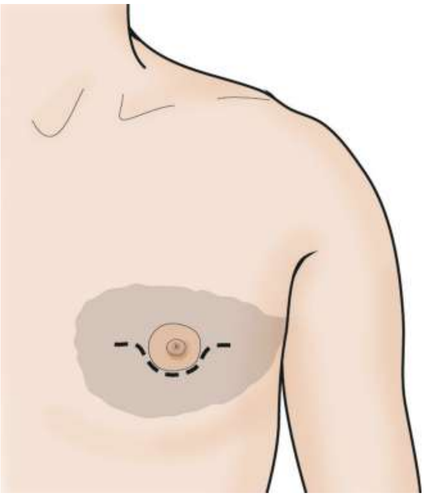
A good cosmetic result should be sought. Circumferential incisions leave better scars than radial incisions, and a scar can usually be hidden at the areolar edge or in the inframammary crease. Subcuticular skin sutures avoid any additional scarring. Incisions in the superomedial quadrant of the breast often result in hypertrophic scars in an area that is cosmetically sensitive – they should be avoided if possible.

The skin scar is not the only cosmetic consideration. A large fibroadenoma displaces and compresses the surrounding breast tissue, and local excision merely returns the breast to its original size. Careful haemostasis, followed by absorbable sutures in the breast tissue and a vacuum drain, will eliminate the dead space and restore the contours of the breast.

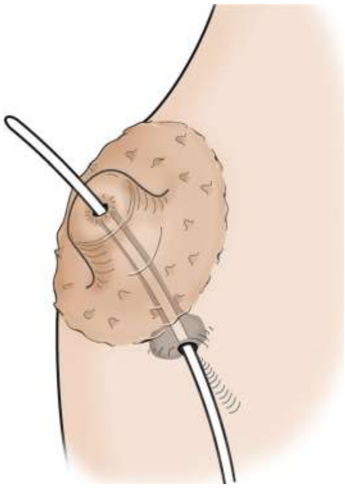
During pregnancy, the breast is significantly more vascular but otherwise poses no difficulties. Surgery on a lactating breast may be complicated by ongoing milk secretion at the operation site. A vacuum drain may compound the problem and establish a milk fistula. The situation may be better managed by repeat aspiration of the milk cyst as it recollects.

TREATMENT OF GYNAECOMASTIA

Power-assisted liposuction and ultrasound-assisted liposuction are the preferred treatment modalities for mild gynaecomastia.[4] An inframammary scar may be a continuing source of embarrassment and it is usually possible to excise even a broad-based breast through an inferior circumareolar incision. Recently, the Benelli round block incision technique has been employed when excess skin needs reduction with superior cosmesis. Dissection is commenced by lifting the areola and nipple from the underlying breast. A little breast tissue should be left attached to the undersurface of the nipple and areola to safeguard the blood supply and also to prevent a hollow in this region due to a lack of subcutaneous fat. The skin is then undermined circumferentially to the edge of the breast tissue, where the plane of dissection comes onto the pectoral fascia. The breast is then dissected off the pectoral fascia and delivered out through the wound. Access is restricted, and much of the dissection cannot be under direct vision; moreover,



5.4 Excision for gynaecomastia can involve the removal of breast tissue extending out over the whole shaded area. Lateral and medial extensions to the initial areolar edge incision may be necessary, but should be avoided if possible. ⏎



5.5 The fine probe is in a mammillary fistula, which extends from a chronic areolar edge abscess to the opening of a duct onto the nipple. ⏎

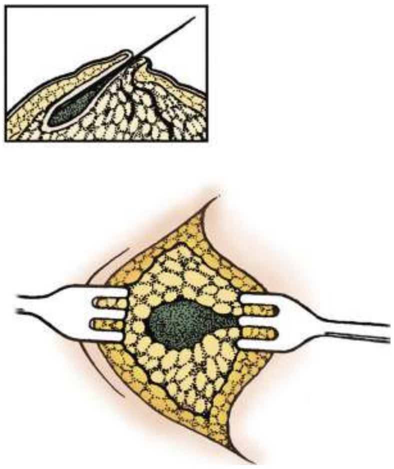
haemostasis is difficult until the whole breast has been excised. If difficulty is encountered, the breast can be transected and removed a quadrant at a time. A small extension at either end of the incision improves access but should be avoided, if possible, as it may result in a more obvious scar (Figure 5.4). Usual complications of surgery for gynaecomastia include seroma, haematoma, infections, inadequate resection, pain and sensory changes.[4] A vacuum drain is recommended, as haematoma formation under the flaps is a common complication.

SURGICAL MANAGEMENT OF BREAST INFECTIONS

Infection occurs most commonly – but not exclusively – in a lactating breast. In the early stage of inflammation, an appropriate antibiotic may be all that is required. Once pus has formed, drainage is required. Repeated aspirations under ultrasound guidance can be attempted if the skin is not involved.[5] Aspirations can be repeated a few days later if more pus collects. There appears to be no contraindication to continuing breastfeeding, and this should be encouraged, especially in areas of the world where it is crucial to the survival of the baby. The cavity can be closed with a few skin sutures after a thorough wash and inserting a drain. When antibiotics have been started too late, the result is frequently a walled-off abscess, which fails to point. Instead, there is a deep indurated mass of inflamed breast tissue within which there may be multiloculated collections of pus. It is important that the surgeon remembers that an aggressive inflammatory breast cancer can mimic a breast infection. Deep pus in the breast is difficult to assess clinically, but can be confirmed by ultrasound. These deep abscesses were traditionally explored under general anaesthesia so that loculi could be broken down. A corrugated drain was left *in situ* to allow continuing drainage and to prevent premature skin closure.

A recurrent or chronic abscess at the areolar edge is suggestive of an underlying *mammillary fistula* (Figure 5.5). Recurrence will continue until the fistula tract has been eliminated. It can be deroofed, but better cosmesis will be achieved if the tract is excised via an approach similar to that shown in Figure 5.6. Recurrent infections deep to the nipple – often associated with nipple retraction and nipple discharge – are usually secondary to *periductal mastitis* and finally lead to the formation of a mammillary fistula. A major duct excision (Hadfield's operation) eradicates the source of the infection.

A chronic granulomatous inflammatory process in the peripheral breast occurring within a few years post lactation has been described in many regions of the world, and is now recognised as *idiopathic granulomatous mastitis*. The inflammation is perilobular on biopsy, and known granulomatous pathology such as tuberculosis is ruled out before treating these cases with steroids, surgical debridement or both. The process seems to be triggered by lactation and behaves in an autoimmune fashion, although conclusive evidence has not been documented.



5.6 A blunt probe or sawn-off needle is introduced into the discharging duct. Excision of this duct can be through either a radial areolar incision or an incision at the areolar edge. ⏎

SURGICAL MANAGEMENT OF NIPPLE DISCHARGE

Discharge from multiple ducts, which occurs in galactorrhoea, requires medical evaluation followed by medical therapy rather than surgical management. Discharge from multiple ducts can also occur in duct ectasia and can further result in periductal mastitis. When symptoms cannot be controlled by other measures, a formal major duct excision is indicated. Discharge from a single duct is also commonly secondary to an ectatic duct. However, if the discharge is bloodstained, an intraductal papilloma or carcinoma should be suspected and an ultrasound-guided core of any visualised ductal lesion should be performed. A microdochectomy is appropriate for copious discharge from a single duct, to alleviate distressing symptoms and to obtain tissue for histology to exclude malignancy.

Microdochectomy

Local anaesthesia is satisfactory, but most patients prefer general anaesthesia for nipple and areolar surgery. The nipple is squeezed to identify the appropriate duct, into which a fine blunt probe is introduced. A lacrimal probe or thick non-absorbable sutures can be inserted into the opening of the duct to help trace the duct. A sawn-off needle has the extra advantage of an eye, which can be used to secure the probe in place with a fine suture for the duration of the operation. The probe is then used to guide the surgeon in the removal of 3–5 cm of the appropriate duct. This can be approached by a radial incision in the areola or by an areolar edge incision, which may be cosmetically superior (see Figure 5.6). After removal of the duct, which is sent for histology, the wound is closed with fine sutures.

Major duct excision: Hadfield's operation

Antibiotic cover is recommended. All the ducts under the nipple and areola are excised via an inferior circumareolar incision. A deep purse-string suture, to encourage nipple eversion before the skin suture is inserted, can improve the final cosmetic result.

SURGICAL MANAGEMENT OF BREAST CANCER

Historical overview of treatment modalities in breast cancer

Surgery of the breast has always been dominated by the management of breast cancer. Although further reading is essential to understand the current position,[6] it is helpful to consider the issues within their historical context, as the surgical focus has evolved over time. Initially, surgeons were striving for cure through increasingly radical operations. This was followed by a search for the optimal place of surgery amongst the other effective treatment modalities. Now the focus has shifted to oncoplastic surgery – a combination of tumour excision and reconstruction.

The *Halsted radical mastectomy*,[7] which included the removal of the whole breast, the axillary contents and the pectoral muscles, was the original gold standard of surgical treatment. The *extended radical mastectomy* was a logical extension that achieved more radical lymphatic clearance by excision of the internal thoracic and supraclavicular nodes. However, morbidity was increased without significant advantages in survival or local control. The pectoralis major was excised in a radical mastectomy, as it was believed that the lymphatic drainage was mainly through the muscle; in addition, removal improved access to the axilla. However, adequate access to the axilla is obtained by pectoral muscle retraction and it is now known that there is no oncological benefit to removing the pectoral muscles and that the lymphatics do not drain via the pectoralis muscle. The radical surgical option is therefore now a *mastectomy* and an *axillary clearance*, in which the pectoralis major and pectoralis minor are retained. The axilla can be approached via either a Patey's modification (pectoralis minor is excised), an Auchincloss modification (pectoralis minor is retracted), which is the commonly used technique, or Scanlon's modification (pectoralis minor is divided but not excised).

Radiotherapy is effective in the treatment of breast cancer, for both primary breast cancer and the axilla. Combining more conservative surgery with radiotherapy gives results comparable to radical surgery. This was shown by the early studies of McWhirter and confirmed by many subsequent trials, namely the EBCTCG and QUART trials.[8,9]

Conservative excision alone of a malignant breast lump often resulted in a recurrence within the breast. Similarly, performing a *total mastectomy* without treatment for the axilla was often followed by axillary recurrence. However, some women were cured without disfiguring surgery or the side effects of radiotherapy, and patients who can safely avoid unnecessarily radical therapy are now easier to identify.

The principle remains, however, that radical treatment includes treatment of the whole breast and axilla by one or other modality unless it can be shown that the individual patient does not require it. Safe avoidance of radical treatment of the breast and of axillary nodes in selected patients relies on the prediction of risk from the characteristics of the primary tumour and/or on the axillary staging operations described in the following section.

Breast cancer responds both to *hormonal manipulation* and to *cytotoxic chemotherapy*, depending on the receptor expression and grade of the tumour. These drugs are used in the control of metastatic disease and also as adjuvant and/or neoadjuvant therapy. Chemotherapy and hormonal manipulation decisions are based on predictions of tumour behaviour. The Nottingham prognostic index is based on tumour size, histological grade and node status.[10] Patient age and menopausal status, as well as the tumour receptor response to hormones, are of additional value when predicting tumour behaviour.

The practice of optimal breast cancer surgery therefore requires cooperation between the surgeon, radiologist, pathologist, radiotherapist and oncologist. Surgeons specialising in breast cancer have been shown to have better results than generalists.[11] This is primarily the result of the appropriate treatment modality being chosen for the individual patient and is dependent on a high standard of histological, cytological and radiological diagnostic services and consensus decisions that are agreed at multidisciplinary meetings. In the developed world, the surgery of breast cancer has therefore been concentrated into specialist units. Surgeons practising in areas of the world where these diagnostic services are suboptimal or where access to radiotherapy or chemotherapy is limited may still have to rely more on the use of radical surgery.

DIAGNOSTIC AND STAGING PROCEDURES

The breast

The patient may have presented with a palpable breast mass, or a suspicious area may have been detected by screening mammography; confirmation or exclusion of cancer must follow. Triple assessment is the combined evidence of the clinical, mammographic and pathological examinations and results in a confident preoperative diagnosis in almost all patients. If these assessments all predict malignancy, treatment can then be planned. Core biopsy is the appropriate technique and has replaced fine needle aspiration cytology in the initial assessment. If the lesion is palpable, the surgeon can take the core biopsy with a specially designed needle passed through a small stab incision in the overlying skin, which has been infiltrated with local anaesthetic. Core biopsy of an impalpable lesion detected on imaging requires mammographic stereotactic localisation devices or guidance by ultrasound. If the histology is inconclusive or does not correlate with clinical and imaging features, WLE is usually the most appropriate next surgical step. This not only will give definitive histology but also is often sufficient surgical treatment of the primary breast tumour if malignancy is finally confirmed.

The axilla

Axillary node involvement is of prognostic importance and affects decisions on both systemic and local treatment. Radical treatment of the axilla by surgery or radiotherapy reduces symptomatic axillary recurrence. However, if the axillae of all patients are treated, about 60% of patients have unnecessary axillary treatment, as they have no nodal secondaries. Axillary clearance should be restricted to patients with a node-positive axilla. Axillary staging is therefore important. Benign axillary nodal enlargement is common and clinical staging of the axilla has little to offer. However, a palpable node that shows an abnormal signal on ultrasound imaging is likely to be replaced by a tumour, and such a node can be sampled by fine needle aspiration or core biopsy.[12] The three operations that are commonly used to stage the axilla are sentinel node biopsy, lymph node sampling and a level I dissection.

A concern over all lymph node staging procedures is that, with more thorough histological examination of fewer nodes, there is a greater chance of detecting a small nodal metastasis, which will change the staging of the patient's cancer. A single node will have more sections examined by the pathologist than each of the 15 nodes from a full axillary dissection. The importance of micrometastasis in all types of tumours is still debated. Histocytochemistry techniques have added a further dimension to this debate, with the identification of isolated tumour cells in a lymph node. Isolated tumour cells are not considered significant in management and do not alter the management strategy.

SURGICAL TREATMENT OF BREAST CANCER

A patient may have a surgically operable tumour at presentation; a tumour that, although operable, could be considered locally advanced; or a totally inoperable locally advanced tumour. In addition, the patient may have a high or low risk of metastatic disease or even proven metastatic disease at the time of presentation. In each situation, the surgeon is aiming for a combination of the best local control with the optimum cosmetic result. However, the role of other treatments, the extent and the timing of surgery and even the advisability of any surgery at all may vary.

OPERABLE BREAST CANCER

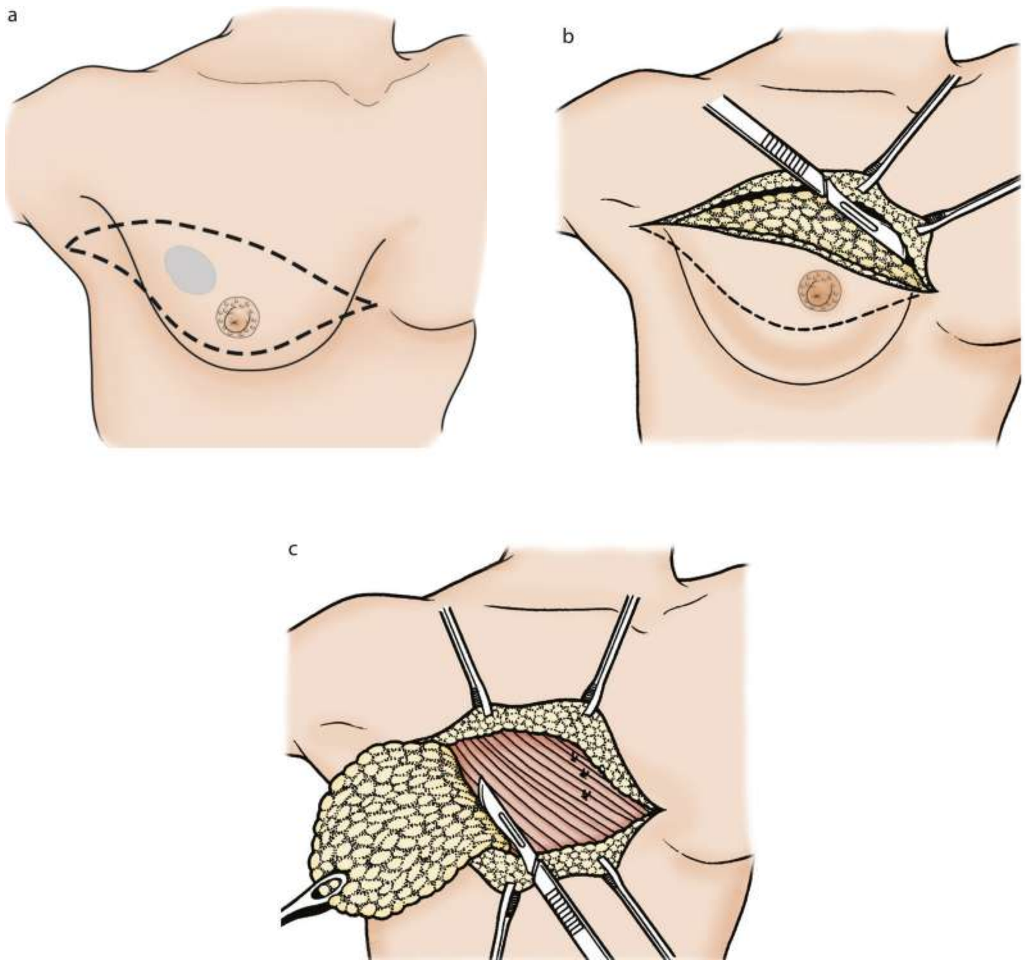
Histologically clear margins on the excised specimen are important. This is usually possible with a WLE. As it is not necessary routinely to excise the skin overlying a breast cancer, skin incisions can be placed in more aesthetically acceptable positions and oncoplastic techniques can be used to achieve good cosmesis. Current recommendations are that there should be no tumour on the inked margin on microscopy for adequacy of surgery. Macroscopically, the surgeon is therefore attempting to keep a 10 mm margin of normal tissue from the cancer. Unfortunately, WLE alone of large tumours in small breasts, or centrally placed tumours, will result in poor cosmetic results. Excisions of over 20% of breast volume will almost always result in unacceptable deformity and the limit is around 10% for inferior and medial tumours. Other strategies should be considered. A mastectomy, with the option of an immediate or late reconstruction, may be preferable. Alternatively, the WLE should be combined with some form of reconstructive procedure, involving either breast tissue displacement or tissue replacement (see the section 'Oncoplastic surgery and breast reconstruction' later in this chapter). There appears to be no oncological advantage in a mastectomy for most patients and the decisions revolve around the aesthetic issues of a satisfactory breast reconstruction. Residual breast or chest wall radiotherapy will more often be indicated after a WLE than after a mastectomy, but many mastectomy patients will still be advised to have radiotherapy to the chest wall. Conversely, there are some patients who have only had a WLE for very small tumours, with wide clear tissue margins, who may be able safely to avoid radiotherapy to the residual breast tissue.[13]

MASTECTOMY

An appreciation of the development of the breast from modified sweat glands deep to the nipple is fundamental to the concept of a mastectomy. The whole breast is excised with an overlying ellipse of skin that includes the nipple and areola. General anaesthesia is routine, but the operation can be undertaken with infiltration of large volumes of a dilute local anaesthetic agent. The patient is placed supine with the arm abducted and supported on an arm board. In order to prevent shoulder capsular strain and nerve damage, abduction should be less than 90° and the elbow should not be at a lower level than the shoulder.

The skin ellipse is marked. A low horizontal ellipse lies in the natural skin creases, but some obliquity affords better access to the axilla while keeping the medial end of the scar low and below the area of visible 'cleavage' (Figure 5.7a). The width of the ellipse is decided by issues of skin closure. Tension should be avoided, but excess skin may give an ugly folded scar and haematoma formation is also more likely.

The skin is incised as planned and the incisions deepened through the subcutaneous fat. The ideal plane of dissection is between the subcutaneous fat and the breast tissue, but it is not an easy plane to follow. Skin flaps that are too thick leave significant residual breast tissue *in situ*, while if the flaps are too thin the skin is in danger of losing its blood supply. The plane of dissection should aim to remove the prominent Cooper's ligaments without compromising the network of vascular supply to the skin at the deep dermal plane. Care should be taken to preserve the perforating vessels from the internal mammary artery at the medial edge of the breast. First the upper flap and then the lower flap are raised until, at the edge of the breast, the plane comes down onto the deep fascia (Figure 5.7b). The medial edge is about 2–3 cm from the midline and the lateral edge short of the latissimus dorsi muscle. The breast is then dissected off the deep fascia from above downwards and multiple bleeding vessels secured (Figure 5.7c). The breast tissue inferolaterally is dissected off the



5.7 A right mastectomy. (a) A slightly oblique ellipse keeps the medial end of the scar low and less conspicuous while also giving good access laterally to the axilla. (b) Dissection of the upper skin flap. The natural plane between subcutaneous fat and breast tissue is followed. (c) The breast is then dissected off the deep fascia from above downwards. When the lateral edge of pectoralis major is reached, the dissection of the axillary tail is continued into the axilla. ⏎

serratus anterior muscle and fascia. If clinical or radiological suspicion of pectoral fascial or muscle involvement is present, a disc of pectoralis fascia and muscle should be excised with the specimen. The axillary tail of breast extends up to the axillary lymph nodal territory with variable overlap. The skin flaps are traditionally closed over vacuum drainage.

Skin-sparing mastectomy

This alternative to a total mastectomy for breast cancer preserves the breast skin envelope for an immediate reconstruction. A circumareolar incision is suitable for excision of a small breast but for a larger breast an additional radial inferior or lateral incision will increase access. Alternatively, an incision similar to that used for breast reduction can be used and the two skin flaps are elevated for access. The nipple and the areola are excised with the breast. The reconstructive alternatives are discussed in the section ‘Oncoplastic surgery and breast reconstruction’ later in this chapter.

SUBCUTANEOUS MASTECTOMY

This is usually the preferred option for a prophylactic mastectomy for patients at high genetic risk of breast cancer. The breast is excised through a lateral or submammary incision, with preservation of all the breast skin, the nipple and the areola. The immediate reconstruction can give excellent cosmesis. After any mastectomy, residual breast tissue can be identified, as there is no clear demarcation between the breast and subcutaneous fat. Thus, this operation does not totally eliminate the risk of death from breast cancer and the term ‘risk reducing’ is therefore preferable to ‘prophylactic’.[14]

SURGERY FOR THE AXILLA

SENTINEL NODE BIOPSY

The first node in the axilla to receive lymphatic drainage from the breast is the relatively constant sentinel node(s), which can be identified by injection of either a radiotracer or a blue dye, or preferably both, into the breast. The aim is to remove any ‘hot’ or blue nodes for pathological evaluation. Up to 5 mL of methylene blue or radiotracer is injected into the intradermal layer in the upper and outer quadrants of the breast in the peri-areolar region followed by gentle massage of the breast for 3 to 4 minutes to ensure passage of the dye to the axilla. During this procedure, any other palpable nodes are removed and included as part of the sentinel node biopsy specimen. Initial concerns about false-negative results have proved unfounded.[15,16]

AXILLARY SAMPLING

When this procedure is combined with a mastectomy or WLE of a malignant lesion, level I nodes below the first intercostobrachial nerves are excised. It only requires entry into the axillary fat to remove the most easily palpable nodes. These are commonly in the lower axilla, and a formal dissection of the axillary vein is seldom necessary.

LEVEL I AXILLARY DISSECTION

A level I axillary dissection removes the lower axillary nodes. The operation follows the same principles of dissection as the level II operation, but the dissection is only taken to the level of the lower border of pectoralis minor.

AXILLARY CLEARANCE

Patients in whom axillary staging has shown involved nodes require treatment of the axilla by either an axillary dissection or radiotherapy. Either treatment improves local control and may also marginally improve survival. A *level III clearance* (the removal of all three groups of axillary glands) is the most radical surgical treatment and is usually reserved for patients who have grossly involved nodes in level II identified intraoperatively. A level II dissection is the more routine clearance of an axilla. The decision on the type of axillary surgery depends on the findings at the initial evaluation. Clinical or radiologically significant axillary lymph nodes warrant an axillary dissection. There is now evidence available regarding the equivalent safety and efficacy of consideration of sentinel lymph node biopsy in patients who at first evaluation had significant axillary nodes and have had complete resolution of the axillary nodes with neoadjuvant chemotherapy.[17] Axillary radiotherapy is an alternative treatment for the axilla when a staging operation shows nodal involvement but is less preferable.

A level II or level III axillary clearance may be performed in conjunction with a mastectomy or a WLE. It may also be undertaken as an isolated procedure when earlier axillary node sampling has shown the presence of tumour cells and surgery is felt to be preferable to radiotherapy.

LEVEL II AND LEVEL III AXILLARY CLEARANCE

A level II clearance removes the level I and II nodes and a level III clearance removes all nodes from levels I, II and III. The patient is placed supine with the arm abducted in a similar position to that used for a mastectomy. It is important that, during the preparation of the skin with antiseptic, the arm is lifted forwards so that the skin over the posterior axillary wall is included, and a sterile drape is placed beneath it. Some surgeons then suspend the forearm, with the elbow flexed, above the patient in preference to placing it on an arm board. This produces less tension in the pectoralis major, which can be retracted more easily.

The axilla is most often explored through a transverse lower axillary incision, which may be the lateral end of a mastectomy incision. It can also be explored through a vertical oblique incision at the lateral edge of the breast when this incision has been used for the breast surgery. When an axillary dissection is undertaken as part of a mastectomy, the breast and axillary contents are excised as a single specimen. The mastectomy dissection can be completed, except for the axillary tail, before entering the axilla. Some surgeons prefer to dissect up the upper flap only and then dissect the axilla, leaving the final freeing of the breast from the chest wall until later.

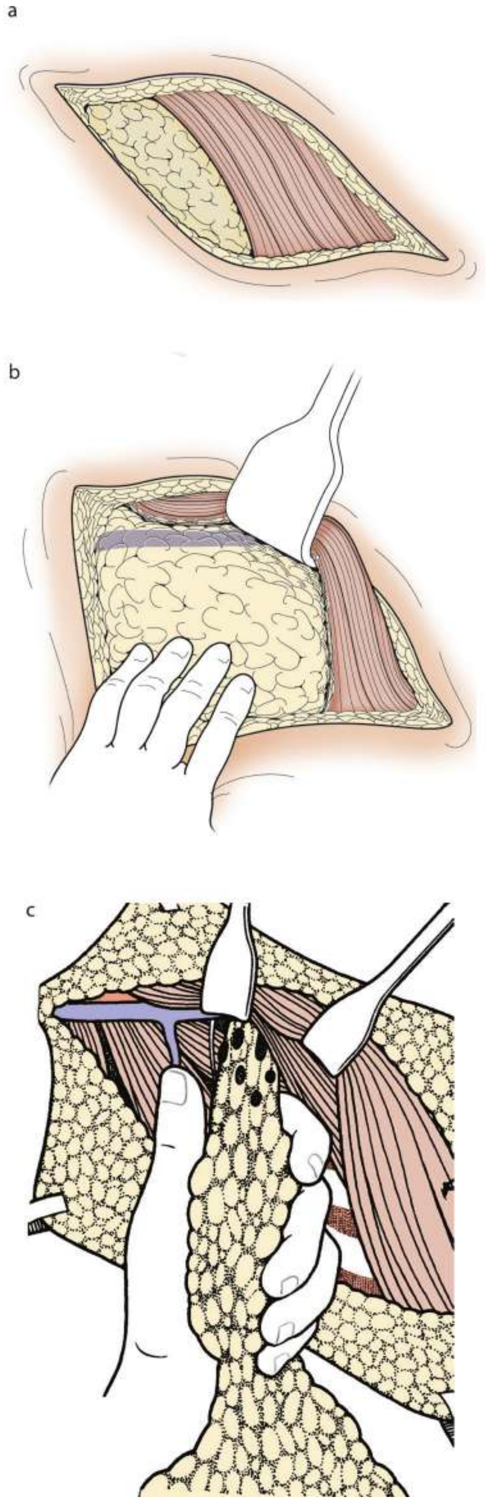
The lateral border of the pectoralis major is defined and the fascia is incised along its length (Figure 5.8a) to allow entry into the axilla. The axillary contents are retracted downwards and the fat is carefully incised over, and parallel to, the axillary vein until the vein is visible (Figure 5.8b). This is the superolateral border of the dissection. Tributaries entering the vein from the axillary fat are secured, divided and ligated. The clearing of the vein continues until the vessels lying on the muscles of the posterior wall of the axilla come into view. The most obvious are the thoracodorsal vessels. (This artery is the branch of the subscapular artery on which a latissimus dorsi flap depends.) The thoracodorsal nerve to the latissimus dorsi emerges from behind the axillary vein just medial to the thoracodorsal vessels and then runs obliquely towards the vessels, forming an easily identifiable triangle on the posterior wall muscles (see Figure 5.2). Both the vessels and the nerve are preserved, but all of the fat and nodes should be dissected off them. The lateral border of the latissimus dorsi is identified and marks the inferolateral limit of the dissection. The vein is then cleared up towards the apex of the axilla, behind the pectoralis minor, which will have to be firmly retracted to obtain sufficient access to perform a level III clearance. The pectoral nerves and accompanying vessels will be encountered, crossing the upper axilla to the anterior axillary wall. The lateral pectoral nerve may have to be sacrificed. The medial pectoral nerve should be preserved if at all possible. Before completing the apical dissection, it is easier to turn attention first to the medial wall and dissect the axillary contents off the serratus anterior.

On the medial axillary wall, the large lateral branch of the second intercostal nerve (the intercostobrachial nerve) is almost immediately encountered entering the axillary fat. Most surgeons sacrifice this nerve, although some try to dissect it out and preserve it. Further posteriorly, the nerve to the serratus anterior tends to be lifted off the muscle with the axillary contents and needs to be carefully freed and allowed to drop back. Once this dissection joins the posterior wall dissection, the remaining apical fat and lymphatics are divided (Figure 5.8c).

Finally, the fat that still attaches the specimen to the skin incision inferolaterally is divided. Haemostasis should be meticulous, but lymphatic drainage will continue and vacuum drainage of the axilla is still favoured by most surgeons. This drain may have to remain *in situ* for 2 weeks.

OPERABLE BREAST CANCER WITH METASTATIC DISEASE AT PRESENTATION

Here, the priority is control of the metastatic disease and, generally, systemic therapy is the initial treatment. Surgery and radiotherapy to the breast and axilla are delayed and the advisability of surgery is reassessed after the response to treatment. If there is a good response, local surgery and radiation may be considered. The recent strategy includes targeting local treatment to those patients who are more likely to benefit, such as those with oligometastatic disease, defined as metastatic tumour of not more than five lesions, in not more than three organ systems, which respond completely or are amenable to ablation therapies.



5.8 A right axillary clearance. (a) The lateral border of the pectoralis major is defined and the fascia is incised along its length to gain access into the axilla. (b) The axillary contents are retracted downwards and the fat over the axillary vein is carefully incised until it can be identified. (c) The apical division of fat and lymphatics is easier after the medial and posterior wall dissection has been completed. (In this illustration, the axillary dissection has been combined with a mastectomy, which has been completed first.) ⏎

LOCALLY ADVANCED BREAST CANCER

A tumour is considered locally advanced when there is extensive skin involvement with peau d'orange or ulceration, fixation to the chest wall or fixed axillary nodes. In these circumstances, neoadjuvant or primary systemic therapy with chemotherapy, newer agents or endocrine manipulation, or both, can bring advanced locoregional disease under control. If the treatment converts the tumour to one that is operable, surgery of the breast and the axilla can then be undertaken as described above, followed by postoperative radiotherapy. If systemic therapy has not had a significant effect on the local disease situation, radiotherapy will usually give better control than surgery. Very occasionally, there is still a place for a surgical salvage operation. It must be remembered, however, that if surgery is through tissue infiltrated by tumour and also damaged by radiotherapy, there is a risk of compounding the problem. These operations follow the standard pattern of wide excision of highly symptomatic malignant infiltration followed by reconstruction, often utilising a myocutaneous flap, onto healthy surrounding tissue.[18]

ONCOPLASTIC SURGERY AND BREAST RECONSTRUCTION

There is a growing appreciation that both oncological and aesthetic principles should be applied in breast cancer surgery. This oncoplastic approach may involve collaboration between a breast surgeon and a plastic surgeon, but increasingly breast surgeons are acquiring plastic surgical skills. Oncoplastic techniques can extend the range of breast-conserving surgery and facilitate both wider resection margins and better post-surgery breast aesthetics.[19]

Safe tumour resection can be combined with breast restoration and/or partial reconstruction, followed by contralateral adjustment if necessary. The choice of technique depends mainly on the size and shape of the breast and the size and position of the tumour, in addition to the preference and experience of the surgeon. Counselling, in parallel with preoperative oncological and aesthetic planning, is critical to a favourable outcome, as patient expectations vary.

Similar aesthetic considerations apply when a mastectomy is indicated. Breast reconstruction can almost always be offered in the developed world and is increasingly requested. There are many factors to consider. Is radiotherapy likely to be indicated and is an immediate or a delayed reconstruction more appropriate? If immediate reconstruction is selected, should a skin-sparing approach be undertaken? Would a flap technique or an implant, or a combination of the two, be the most appropriate method? There are several possibilities and much revolves around whether the patient is to have postoperative radiotherapy. If no radiotherapy is advised, an immediate reconstruction after a skin-sparing mastectomy can give an excellent result, but radiotherapy can cause some deleterious cosmetic changes.[20] Delayed post-radiotherapy reconstruction after a mastectomy poses other challenges. The skin has lost elasticity and a tissue expander cannot create an adequate pocket. In addition, the scar frequently crosses what would be the dome of the reconstructed breast. Usually, in delayed reconstruction, a myocutaneous pedicled flap, utilising either the latissimus dorsi or the rectus abdominus muscle, provides skin and bulk.

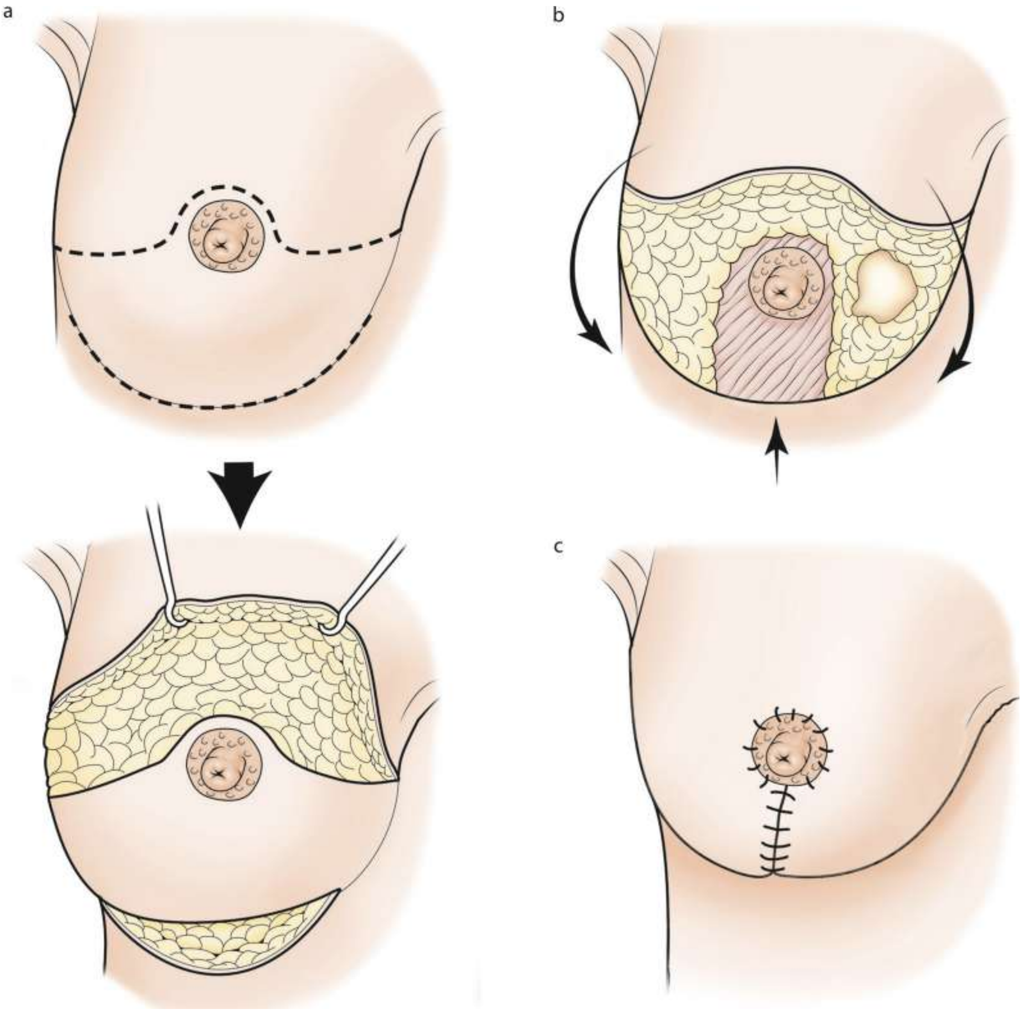
An approach called the 'immediate/later' or 'sandwich' technique can be used to retain breast skin after a skin-sparing mastectomy when radiotherapy is likely. A tissue expander is employed, which is overexpanded during the period of radiotherapy. Subsequently, the space is definitively filled with a smaller permanent prosthesis or a myocutaneous flap.

Free flaps require specialist microvascular skills, which are unlikely to be available outside the largest specialist breast or plastic units. When a flap does not contain sufficient bulk to replace the excised breast, the flap can be combined with a silicone implant or a reduction mammoplasty can be performed on the contralateral breast to achieve symmetry.

VOLUME DISPLACEMENT/REDUCTION

Volume displacement involves parenchymal redistribution and, sometimes, skin and subcutaneous tissue redistribution, after resection of breast cancer.[18] This can be as simple as breast disc mobilisation and primary suture after a segmental resection. In this case, minimal skin mobilisation is necessary and usually no contralateral breast reduction. For larger resections in larger ptotic breasts, a Wise-pattern reduction with wide elevation of skin flaps and a central mound approach to retain nipple and areolar viability enables resections in all areas of the breast (Figure 5.9). Alternatively, a tumour-adapted mastopexy can be orientated to the breast resection (Figure 5.10). Contralateral symmetry surgery is usually necessary following these procedures. For central resection involving loss of the nipple/areolar complex, a Grisotti flap of skin on a dermo/glandular pedicle is a simple way of restoring the central breast area (Figure 5.11).

To facilitate postoperative radiotherapy, marking the tumour cavity with metallic clips prior to repair of the breast disc will be necessary, as the skin incisions



5.9 Wise-pattern reduction mammoplasty. (a) Skin incisions, which can provide access to all parts of the breast by elevation of flaps. (b) All of the exposed breast tissue can be excised. The epithelium is then shaved off the retained hatched area to form the pedicle on which nipple and areolar viability depends. The orientation of this pedicle can be modified according to the position of the tumour. (c) The breast disc has been reconstituted by glandular rotation and the skin trimmed and re-draped. The nipple and areola have been lifted. ⏎

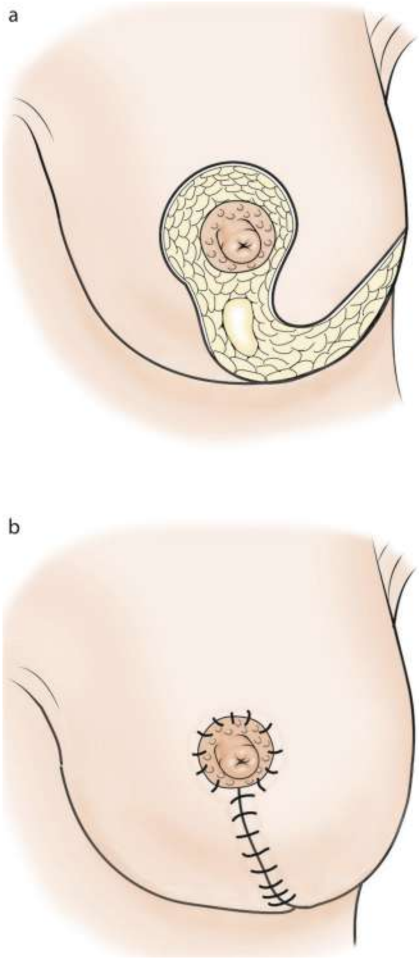
give little clue to the site of the tumour bed when these techniques are employed.

VOLUME REPLACEMENT

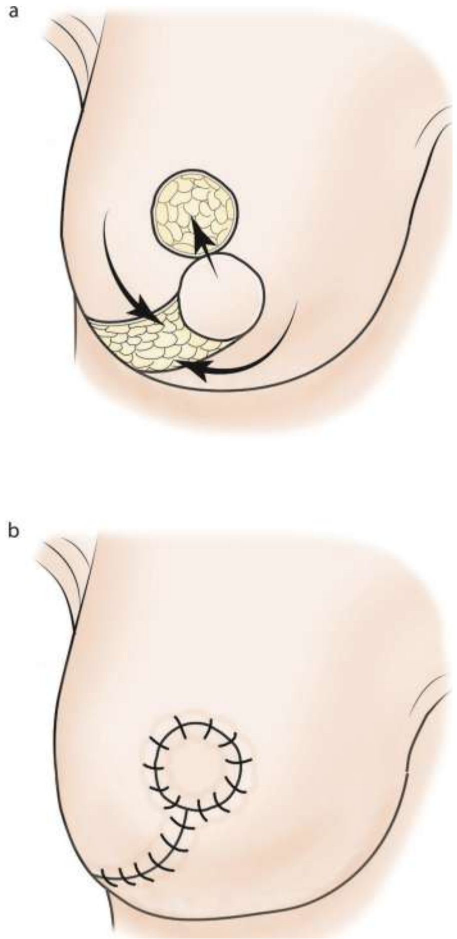
Larger resections are possible, without the need for contralateral symmetry surgery, if the original breast volume and shape can be restored by volume replacement. Implants are unsuitable, as radiotherapy will usually be advised. Autologous tissue replacement employs local flaps with axial blood supply, such as the lateral thoracic adipocutaneous flap or a myocutaneous or myosubcutaneous flap, usually the latissimus dorsi flap or 'mini' flap.

Latissimus dorsi mini flap

This myosubcutaneous flap of the latissimus dorsi is used for volume replacement in the lateral half of the breast. It can be undertaken at the same time as the initial surgery, but some surgeons delay for a few days to have confirmatory histology of the clearance margins before proceeding.[21] The WLE is undertaken with careful preservation of the overlying skin. The flap is harvested from within the axilla at the same time as any axillary surgery, such as a sentinel node biopsy or a full axillary dissection. The vascular pedicle (thoracodorsal neurovascular bundle) is carefully isolated and the latissimus dorsi muscle is dissected free of the underlying serratus anterior muscle and chest wall. The subcutaneous plane is developed to allow isolation of an area of muscle and fat large enough to more than fill the breast defect, as shrinkage of the tissue in the flap occurs over time. Division of the latissimus dorsi tendon prevents later retraction of the flap, which is then rotated into the defect and fixed to the cavity walls.[22]



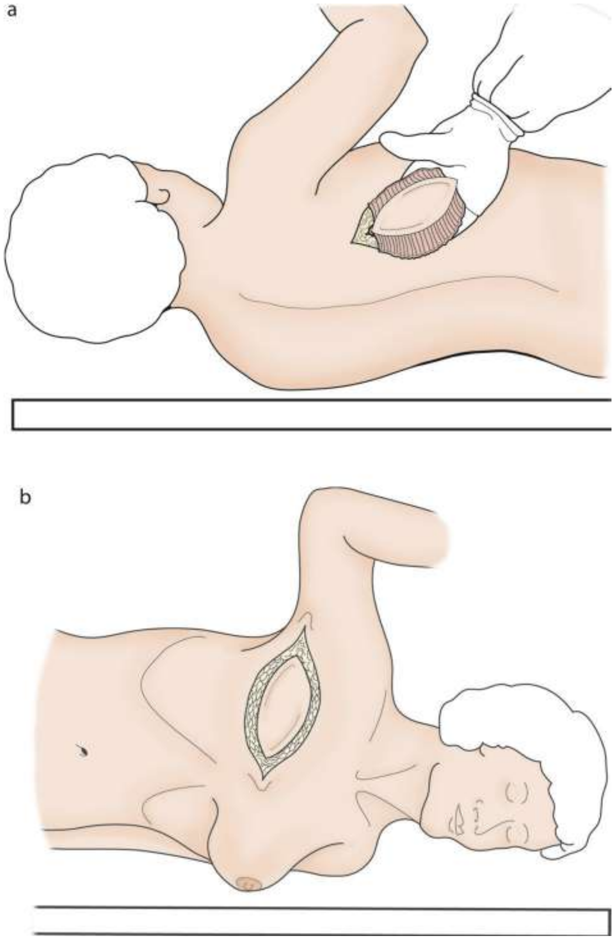
5.10 The tumour-adapted mastopexy, orientated to the position of the tumour, combines tumour resection with a breast reduction and lift. ⏎



5.11 Grisotti flap. (a) A wide local incision of a central lesion has included the nipple and areola, and a skin paddle based on a dermoglandular pedicle has been prepared. (b) Advancement of the flap restores skin and breast tissue into the central defect. ⏎

Latissimus dorsi musculocutaneous flap

This is the most widely used method of breast reconstruction following mastectomy. After completion of the mastectomy and any axillary clearance, the patient is turned on her side and a suitably sized ellipse of skin marked overlying the latissimus dorsi muscle. The long axis of the skin ellipse, or ‘paddle’, can be made in a variety of directions. It may be made transverse to hide the scar under the bra strap, or it may be made perpendicular to the muscle fibres, as this is the line of maximum skin laxity. The paddle is placed sufficiently posteriorly, and inferiorly, to afford adequate length to the flap (Figure 5.12a). The skin is incised, leaving the ellipse attached to the underlying latissimus muscle. Skin and fascia are dissected off the muscle proximal and distal to the skin ellipse to expose the boundaries of the muscle. Deep dissection commences at the anterior border and proceeds medially and inferiorly. The inferior extent of the muscle is attached to the ribs and intermingles with the origin of the external oblique muscle, from which it can be difficult to differentiate. The medial attachment to the thoracodorsal fascia is divided carefully, continuing cranially where it is deep to the inferior origin of the trapezius. The upper border is defined and dissected towards the angle of the scapula and superolaterally to the latissimus dorsi tendon. Further careful deep dissection identifies the thoracodorsal vessels, on which the flap viability depends, and the branch to the serratus anterior, which is also preserved if possible. Dissection is carried along the flap pedicle and tendon of insertion until the flap can be rotated and passed subcutaneously around the chest wall to fill the breast defect (Figure 5.12b). Occasionally, it may be necessary to divide the tendon to allow adequate flap positioning. The neurovascular bundle is particularly at risk during tendon division and must be



5.12 A right latissimus dorsi reconstruction. (a) An ellipse of skin just below the scapula is raised with its underlying portion of the latissimus dorsi. The posterior origin of these muscle fibres is divided to create a compound flap on a pivot point close to the origin of the subscapular artery. (b) The myocutaneous flap is rotated and tunnelled subcutaneously into the mastectomy wound defect. The donor site is closed as a linear scar. ⏎

identified accurately and protected. The donor site is closed over suction drains and the patient returned to the supine position. The latissimus dorsi muscle forms all or part of the tissue replacement for the excised breast and is sutured to the underlying pectoral fascia. In an immediate breast reconstruction, with skin sparing via a circumareolar incision, the skin ellipse is de-epithelialised except for the area required for areolar replacement. In a delayed reconstruction, the skin ellipse is sutured to the upper and lower mastectomy flaps. A silicone implant is often required deep to the flap to provide additional volume.

Transverse rectus abdominis musculocutaneous flap

The transverse rectus abdominis musculocutaneous (TRAM) flap is preferred by some surgeons to a latissimus dorsi flap. Greater muscle bulk can be obtained, and not only does the transverse lower abdominal skin paddle provide skin of a better match, but its removal may also improve the appearance of the stretched lower abdominal skin. The pedicled TRAM flap is brought up by mobilisation of the whole of the opposite rectus muscle on the somewhat perilous blood supply of the internal thoracic artery. A free TRAM flap, or a free deep inferior epigastric artery perforator (DIEP) flap, based on the inferior epigastric artery, is increasingly employed where microsurgical skills are available. A free TRAM flap only sacrifices a small portion of the rectus abdominis with reduced donor site morbidity. The free DIEP flap contains no muscle.

Perforator flaps

Tissue-based flaps, using the redundant skin and/or subcutaneous tissue of the lateral chest wall adjacent to the breast, by rotation based on reliable perforator vessels from the lateral thoracic or intercostal arteries are increasingly being used. The advantages offered are a reliable blood supply, and easy detection using a handheld Doppler, which is not required with increasing experience and surgery, can be performed by the primary surgeon in the same position as the breast procedure. The lateral thoracic artery perforator and the lateral intercostal artery perforator are the common ones employed either separately or combined. Similar flaps can be employed from tissue inferior and medial to the breast for primaries in corresponding locations.

Silicone implants

Implants are used mainly as additional bulk when a latissimus dorsi flap alone is insufficient to achieve symmetry, but they can also replace the whole breast after a skin-sparing or subcutaneous mastectomy. The implant is placed, when possible, partly deep to the pectoralis major muscle. Silicone implants are also used for the complete, or partial, failure of breast development and are the most common form of breast augmentation in the field of cosmetic surgery.

Late complications include implant rupture and silicone leakage. Capsular contracture around an implant is not uncommon, with a worsening cosmetic result. This is a particular problem when the implant has been inserted prior to radiotherapy.

AREOLAR AND NIPPLE RECONSTRUCTION

Many patients are satisfied with the breast mound reconstruction and opt for no further surgery. Prosthetic adhesive areola/nipple complexes are available and, if tailor-made by a cast taken from the other breast, can be very satisfactory. Alternatively, a nipple can be fashioned by a local skin flap or by a nipple-sharing graft from the other breast. Tattooing can then reproduce the colour of the contralateral areola.

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6

Surgical access to the abdomen and abdominal wall

Ciaran Walsh and Greg Simpson

GENERAL CONSIDERATIONS

Surgical access to the abdominal cavity is via the abdominal wall and is required to perform intra-abdominal surgery either by minimally invasive surgery (MIS) or by an open surgical approach. The majority of elective intra-abdominal surgery is now carried out by a minimally invasive technique, by either laparoscopic or robotic-assisted surgery. For both open surgery and MIS, it is important to select incisions that facilitate safe and expeditious surgery. Some of the incisions for MIS port sites may be converted to specimen extraction sites or sites for extracorporeal bowel delivery to facilitate an extracorporeal anastomosis. These sites all need careful planning to account for these specific requirements.

Some intra-abdominal and abdominal wall operations are not suitable for an MIS approach and an open incision is needed. It is crucial that the incision permits the safe performance of the key parts of the operation. Cosmesis may be considered but should not be the primary objective.

The field of abdominal wall surgery incorporates repair of complex abdominal wall defects incorporating abdominal wall hernias and enterocutaneous fistulae, which are usually sequelae of major abdominal sepsis and infected abdominal wall incisions. Computed tomography (CT) scanning, where available, gives us an enormous amount of preoperative information that aids surgical planning and incisions. It is now unusual in elective surgery not to know the purpose and nature of the surgery needed and generally to have enough information to plan the optimal surgical approach in advance. This is equally the case for abdominal wall surgery as it is for intra-abdominal surgery, and a good working knowledge of CT scanning, including the benefits of multiplanar reconstruction, is increasingly important for surgeons working in the abdomen and on the abdominal wall. Anatomical knowledge is the keystone supporting high-quality intra-abdominal and abdominal wall surgery.

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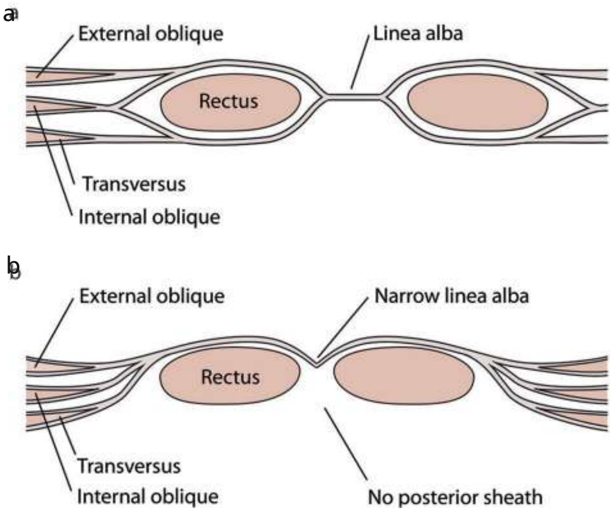
ANATOMY OF THE ABDOMINAL WALL

An excellent knowledge of the anatomy of the musculo-aponeurotic layers of the abdominal wall, with their components and contents, is truly important to perform optimal abdominal surgery. Without this knowledge, you cannot access, close or repair the abdomen in the most appropriate way. Optimal functional and cosmetic outcomes, with the least potential complications, depends on this core knowledge. It is even more important when considering abdominal wall surgery for hernias with, or without, abdominal wall reconstruction (AWR). Attempting the latter without this anatomical knowledge will lead to poor outcomes due to an inability to recognise and understand the pathological anatomy brought about by trauma, hernia, previous surgical scars, mesh or all of the above. It also prevents one from safely modifying the anatomy to repair defects whilst preserving or restoring function.

Below the skin is the subcutaneous fat, deep to which is a condensation of fascia called Scarpa's fascia. Below this is a further fat layer and deeper still are the muscles with their fascial coverings. Deep to the muscles is the transversalis fascia followed by extraperitoneal fat of variable thickness depending on site and body habitus. Next is the parietal peritoneum creating a visceral sac around the intraperitoneal contents.

The abdominal muscles consist of a pair of anterior, vertically oriented strap muscles, each encased in a fascial sheath that is fused together along their length in the midline (linea alba). The rectus abdominis strap muscles run vertically on either side of the midline from the bottom of the rib cage to the pubis. Lateral to these vertical rectus abdominis strap muscles are three flat, sheet-like muscles that are variably muscular and aponeurotic in different sites. They lie one on top of the other in layers. These three oblique muscles – which are, from outside to in, the external oblique, the internal oblique and the transversus abdominis muscles – originate around the perimeter



6.1 The rectus sheath is formed from the aponeuroses of the external oblique, internal oblique and transversus. **(a)** A transverse section of the sheath between the xiphoid and the umbilicus above the arcuate line. **(b)** A transverse section of the sheath in the lower quarter of the abdomen below the arcuate line. ⏎

of the abdomen and insert into, and form, the edges of fascial sheath of the two vertical straps in a variety of different ways. How they do this varies at different levels in the abdomen. Conceptually, this configuration reflects thoracic anatomy, whereby the sternum is replaced by the pair of vertical muscular straps and the ribs and costal cartilages are replaced by the oblique muscles and their aponeuroses, thus creating a musculo-aponeurotic cage that encases the abdomen from chest to pelvis. Figure 6.1 illustrates these principles.

ABDOMINAL WALL MUSCLES

Each rectus abdominis muscle lies alongside the linea alba and runs from the front of the pubis inferiorly to the xiphoid process and beyond to the fifth, sixth and seventh costal cartilages. Each muscle is encased in a fascial rectus sheath formed by the aponeuroses of the external oblique, internal oblique and transversus abdominis as they come medially. The substance of the rectus abdominis muscle is traversed by three horizontal *tendinous intersections*, one opposite the umbilicus, another near the xiphoid and a third midway between these. The three fascial intersections traversing the muscle fuse with the anterior sheath but not the posterior sheath. In general, the three oblique muscles originate from the lower ribs, the iliac crest and the lumbar fascia. As they traverse the front of the abdomen, all three become aponeurotic and are inserted mainly into the linea alba. Before they reach the linea alba, they combine to form a sheath for the rectus muscle. Above the umbilicus, the linea alba is 1–2 cm wide, but in its lower part is narrower.

The external oblique runs mainly downwards, forwards and medially, but its upper fibres are nearly horizontal. Its lower fibres, inserting into the iliac crest, are nearly vertical. Its lower free border forms the *inguinal ligament*, which stretches from the anterior superior iliac spine to the pubic tubercle. The internal oblique mostly runs in a slightly upwards and medial direction, but its lowest fibres, which descend to the pubis, are almost vertical.

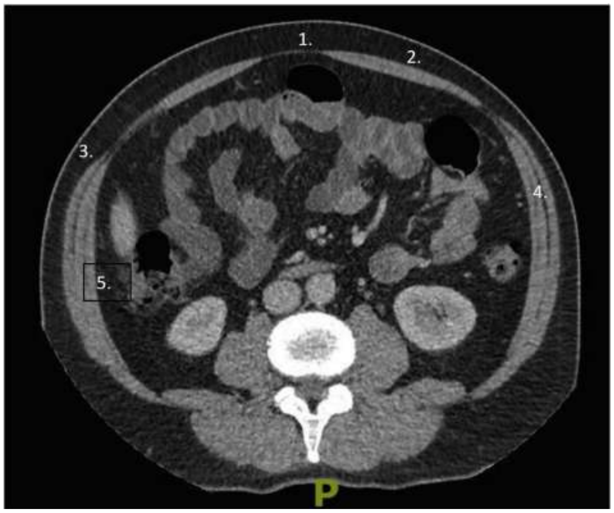
The transversus abdominis is the deepest muscle and it runs mainly horizontally, although its lowest fibres run downwards along with those of the internal oblique as the conjoint tendon. Superiorly, its origin is from the costal margin. The transversus abdominis deep surface is lined by transversalis fascia, which lies between the muscle and the peritoneum. In the lower abdomen, the transversus does not run behind the recti (see Figure 6.1). The lowermost edge of the transversus abdominus, behind the recti, represents the arcuate line.

NEUROVASCULAR SUPPLY OF THE ABDOMINAL WALL

The innervation of the abdominal wall is via thoraco-abdominal and abdominal spinal nerves along with the ilioinguinal and ilio-hypogastric nerves. The former run in the neurovascular plane between the transversus abdominus and the internal oblique. Skin innervation is via cutaneous branches more laterally, whereas medially, overlying the recti, it is from anterior terminal branches that have pierced the rectus sheath at the linea semilunaris (Figure 6.2).

The segmental blood vessels also run forwards towards the rectus sheath, in the plane between the transversus abdominus and the internal oblique. The blood supply of the abdominal wall lateral to the rectus sheath is predominantly via these segmental intercostal and lumbar arterial vessels, whereas the blood supply of the recti and the overlying lipocutaneous tissue is via the epigastric vessels. The superior epigastric is a branch of the internal mammary artery and the inferior epigastric is a branch of the femoral artery. From their respective origins, they enter the rectus sheath and supply the muscles and then, via perforator vessels, particularly around the umbilicus, provide blood supply to the skin and fat superficial to these two muscles.

Deep to the muscles, with their surrounding fascia, there are two layers of connective tissue separating them from the visceral peritoneum of the intraperitoneal organs. The innermost is the parietal peritoneum, which lines the entire abdominal cavity covering the anterior and posterior abdominal walls, the undersurface of the diaphragm and the cavity of the pelvis. Between the peritoneum and the abdominal wall is a



6.2 CT anatomy in cross section. Axial slice showing the recti and the obliques. 1, linea alba; 2, rectus abdominis; 3, external oblique; 4, internal oblique; 5, transversus abdominis. ⏎

layer of extraperitoneal areolar tissue, which varies in thickness in different places and carries the name of the abdominal component it lies under. In the anterior abdominal wall, this is referred to as the transversalis fascia but is contiguous with a similar layer elsewhere surrounding the external surface of the parietal peritoneum, such as the diaphragmatic fascia on the undersurface of the diaphragm. There may be a variable amount of extraperitoneal fat between the parietal peritoneum and the transversalis fascia.

APPLIED SURGICAL ANATOMY OF THE ABDOMINAL WALL

MUSCLES AND FASCIA

It is common for there to be a variable aponeurotic diastasis between the recti. Up to 2 cm is a normal physiological variant but the diastasis can be much wider. This is important to remember when planning where to make the initial incision in the posterior rectus sheath when performing a retrorectus Rives–Stoppa–Wantz hernia repair operation. Preoperative assessment of a CT scan will inform you of the width of the linea alba.

There are no fascial interconnections on the posterior aspect of the rectus abdominus muscles between the muscles and the posterior rectus sheath, unlike on the anterior surface of the muscle, where they correspond with the tendinous intersections of the rectus muscles at the level of the xiphoid, the umbilicus and halfway between the two. This is the reason one can do a retrorectus dissection with ease and why a posterior rectus sheath nerve block works, because the local anaesthetic can run freely along the length of the posterior aspect of the muscle and block nerves along the length of the linea semilunaris. The nerves and vessels that have come forwards in the neurovascular plane, and then pierce the posterior rectus sheath, make up a line along the lateral extent of the rectus muscle within the surgically dissected retrorectus space. This is the linea semilunaris. Surgically, you cannot go lateral to this lateral extent of this fascial pocket without dividing some tissue and, thus, this is the lateral extent of a retrorectus surgical dissection and as far lateral as one can lay a retrorectus mesh, without making further musculo-aponeurotic incisions. Furthermore, one must stop the lateral dissection in the retrorectus space, just medial to these nerves, to avoid denervation and dysfunction.

The transversalis fascia is a part of a continuous connective tissue areolar layer of variable thickness that surrounds the parietal peritoneum. The transversalis fascia lies posterior to the transversus abdominus muscle and anterior, or exterior, to the peritoneum and is contiguous with the fascia diaphragmatica on the undersurface of the diaphragm. There are two lamellae, one of which is very near and ‘hugs’ the peritoneum and the other ‘hugs’ the muscle fibres of the transversus abdominis. When performing a transversus abdominis release, one can dissect between these layers, but the peritoneum can get very thin, and it may be preferable to dissect immediately onto the muscle fibres to prevent visceral sac defects.

There is no posterior rectus sheath in the lower abdomen (below the arcuate line). Therefore, there is only transversalis fascia and peritoneum, behind the recti, at this level.

The transversus abdominus muscle fibres lie behind the upper medial aspect of the rectus abdominus muscles. This is where these fibres are accessed to start the upper end of a transversus abdominus release when performing a posterior components separation operation.

The transversus abdominus muscle takes its superior origin from the posterior aspect of the costal margin. Therefore, to get behind and above the costal margin, you have to be behind the transversus abdominus. When you are in this plane you can dissect up to the central tendon of the diaphragm.

FAT PADS AND PLANES

There is a critically important pad of fat around the inferior epigastric vessels, which is important to recognise during Rives–Stoppa dissection to firstly prevent injury to the inferior epigastric vessels and secondly to guide you down in the correct plane to Cooper’s ligaments.

Just lateral to the rectus sheath there is a fat pad between the posterior aspect of the external oblique and the anterior surface of the internal oblique. This is an important landmark when performing an anterior component separation and tells you that you are in the correct plane.

BLOOD VESSELS

The blood supply to the rectus abdominis muscles comes mainly from the inferior and superior epigastric vessels. These vessels give off perforators that traverse the anterior rectus sheath to vascularise the lipocutaneous paddle anterior to the rectus muscles (so-called zone 1). The perforators around the umbilicus are particularly important in this regard and need to be preserved, when possible, during surgery. The inferior epigastric vessel is particularly important and must be spared in abdominal surgery when making stomas and other incisions, wherever possible. In AWR surgery, it is critical to protect the inferior epigastric artery.

NERVES

The intercostal and oblique running spinal nerves run in the plane between the transversus abdominis and the internal oblique. They pierce the rectus sheath in the lateral-most recess of the rectus fascial pocket, just lateral to the lateral aspect of the rectus muscle, and from this point they innervate the lipocutaneous paddle over the rectus muscles via their terminal branches. This anatomy of the nerves also explains the anatomical basis of laterally placed ultrasound-guided nerve blocks, as well as the rationale for rectus sheath catheters delivering local anaesthetic for postoperative analgesia after midline incisions.

In the lower abdomen, it is important to identify the surface marking of the ilioinguinal nerve 1 cm medial to the anterior superior iliac spine in order to avoid this with surgical incisions or drains.

PATIENT POSITIONING

It is important for the abdominal surgeon to have a very good understanding of different patient positions when performing abdominal surgery. This is particularly the case for minimally invasive abdominal surgery. In open abdominal surgery, the patient will usually either be supine or be in a modified legs-up position with the legs in limb supports (stirrups) that can be moved at will intraoperatively. The legs elevated in stirrups has an enormous advantage in pelvic surgery, as access to the pelvis is aided by this position and it also provides a place for a further assistant to stand, that is, between the legs. Additionally, the legs-up position facilitates intrarectal manipulation and insufflation, intraoperative endoscopy and transanal stapling. The importance of movable limb supports is that, while the patient has their legs apart permitting access, the legs can also be lowered at will, which significantly reduces the risk of ischaemia reperfusion vascular injury to the lower limbs.

In laparoscopic surgery, the patient position often mirrors that of the open version of the operation with some additions, particularly due to the extreme head- or side-down position that may be needed to facilitate vision and access. If the table angle is to be changed to facilitate movement of viscera away from the operative site, the patient must be secured on the table with shoulder supports, chest or leg straps, or specifically designed mattresses aimed at ensuring the patient does not slip on the operating table. Consideration must be given to the ergonomics of the laparoscopic operation when positioning the patient, ensuring that the patient's position does not impede manipulation of instruments outside the abdomen.

INCISIONS FOR ELECTIVE OPEN ABDOMINAL SURGERY

Figure 6.3 demonstrates common open and laparoscopic abdominal incisions.

MIDLINE INCISIONS

Midline incisions give good general access to the abdominal cavity, particularly in an emergency. Midline incisions are easy and quick to perform, as the lipocutaneous layers are relatively bloodless and the linea alba is easy to identify. In obese patients, lateral traction on the subcutaneous fat during incision will naturally lead one to the midline and the linea alba. Great care needs to be taken if there are hernias or if there has been previous surgery, to avoid inadvertently entering a hernia sac or the peritoneal cavity, with subsequent damage to an intraperitoneal structure. In the unoperated abdomen, once you get to the midline fascia, stop and decide where you want to enter the peritoneal cavity. Use a scalpel between clips, but be aware that there is a variable amount of extraperitoneal fat. Open the peritoneal cavity under direct vision with a scalpel, having ensured no intraperitoneal contents are attached. Once the peritoneum is opened, air will enter and vision within the abdomen is better. The incision can be extended under direct vison whilst at the same time running a finger under the peritoneum to make sure nothing is attached to the posterior aspect of the parietal peritoneum. Enormous care needs to be taken in the re-operative case, as bowel loops may be stuck to the back of a previous midline wound. In these cases, abdominal entry can actually be one of the most difficult and dangerous parts of the surgery, as inadvertent enterotomies can greatly increase morbidity. Aim to enter the peritoneal cavity away from previous surgical scarring, if possible. If it is obvious that the small intestine is stuck to the back of the midline wound, then one can go laterally, superficial to the posterior sheath, and then try to enter the peritoneal cavity just lateral to the midline. Either way, great care is needed.

As well as good general access, the midline incision is quick and easy both to perform and to close accurately. The main disadvantage of a midline incision, apart from cosmesis, is that midline incisions have a higher incidence of incisional hernias than off-midline incisions.

PARAMEDIAN INCISIONS

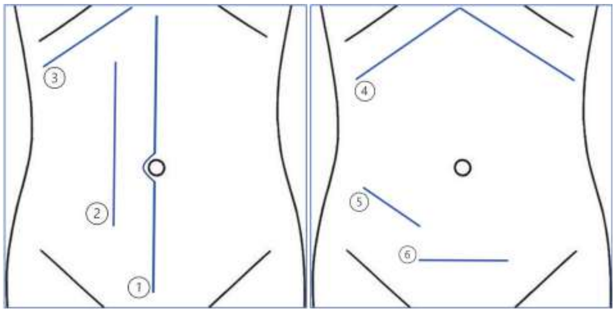
Paramedian incisions are no longer regularly used for a variety of reasons, including the current availability of longer-lasting absorbable sutures for midline closure, the interference of a paramedian incision with stoma sites and the potential for rectus abdominus atrophy if neurovascular injury occurs. In essence, the skin is incised to one side of the midline, cutting down to the anterior rectus fascia, which is then incised. Deep to this, the rectus muscle is identified and retracted laterally, before incising the posterior rectus sheath in the same line as the anterior sheath and skin incision, after which the peritoneum is incised.

MUSCLE-CUTTING INCISIONS

These may be transverse oblique subcostal incisions or bilateral oblique subcostal incisions creating a so-called rooftop incision or combined transverse and vertical incisions (L or reverse L incision). These incisions may give better access to specific areas of the abdomen for elective surgery, for example pancreatic or liver surgery. Transverse incisions are less prone to incisional hernia formation, are more cosmetically attractive and have fewer adverse effects on respiratory function after surgery, particularly if the incision is in the lower abdomen. They have the disadvantage of causing atrophy of the rectus abdominus and interfering with potential stoma sites.

PFANNENSTIEL INCISIONS

The superficial component is a low transverse suprapubic incision through the skin, subcutaneous fat and rectus sheath, which is followed by a vertical incision in the lowermost linea alba between the recti.



6.3 Common open and laparoscopic abdominal incisions. 1, midline; 2, paramedian; 3, Kocher's; 4, rooftop; 5, gridiron; 6, Pfannenstiel. ⏎

CLOSING ABDOMINAL INCISIONS

The ideal technique to close an abdominal incision promotes optimal and timely tissue healing, provides adequate protection to the viscera and acts as a barrier to infection; in addition, it has adequate tensile strength in the short and long term to produce good abdominal wall function. The technique should be efficient, be reproducible and have a low incidence of complications. All of this needs to be aligned to the context of the particular surgery being performed and the therapeutic priorities, whether in an emergency or an elective setting and regardless of whether the surgery is open or by a minimally invasive technique. Debate continues on the best way to close the abdomen in nearly all circumstances.

Sadly, incisional hernias are common, and every effort needs to be made to prevent them, as they can significantly impair quality of life, not to mention lead to emergency presentations in their own right, be that from bowel obstruction or strangulation.

Preventing surgical site infections (SSIs) and other surgical site occurrences (SSOs) such as haematoma and seroma is one of the most important factors in preventing incisional hernias. SSI prevention bundles are key tools in surgical practice. Prophylactic intravenous antibiotics, patient warming, adequate skin preparation and draping, and glove and instrument changes prior to commencement of closing the abdomen are all within the surgeon's sphere of influence, as are technical factors such as tissue handling with meticulous technique and haemostasis. When combined with preoperative measures such as smoking cessation and haemoglobin A1c control, all these factors make a significant difference to SSOs. In abdominal surgery generally, and in AWR in particular, we advocate following recent guidance from the Royal College of Surgeons and the Royal College of Anaesthetists on the use of tranexamic acid pre- and postoperatively to try to reduce postoperative bleeding complications.

CLOSING A MIDLINE LAPAROTOMY

It is recommended to use a small-bites technique with a continuous 2/0 gauge monofilament slowly absorbable suture (e.g. 2/0 polydioxanone [PDS]) taking bites 5 mm apart and 5–9 mm from the wound edge. Only the anterior fascia or aponeurosis is included in the suture, as this is the structure that needs to be closed. Sutures are begun and finished with self-locking knots that do not weaken the suture and reduce its tensile strength. One should aim for a 5:1 suture-to-wound length ratio. Fascial closure is followed by interrupted dermal sutures of absorbable monofilament suture material, and then a subcuticular suture is used to close the skin. When there is a stoma present, the authors favour the use of skin glue after the subcuticular sutures are placed and, in this case, no wound dressing is used. In high-risk wounds, a vacuum-assisted wound dressing may be used. There does not appear to be any strong evidence in favour of antimicrobial sutures.

In patients at high risk of incisional hernia (e.g. patients with aortic aneurysms), prophylactic mesh augmentation after elective midline laparotomy can be considered. Mesh augmentation after suture closure of a midline abdominal incision reduces the rate of incisional hernia compared with primary suture closure. There does not appear to be an increased risk of SSI. Data on the incidence of burst abdomen and postoperative pain are limited.

CLOSING A REDO MIDLINE LAPAROTOMY

Make the decision on the technique based on the quality of the fascia and surrounding tissues. Unlike that for the index laparotomy, there are no good-quality data for the use of the small-bites closure technique in redo laparotomy closure. We favour a small-bites technique if fascial quality is adequate and fascial anatomy is clearly seen, such that one can readily see the edge of the fascia and identify it accurately and not mistake it for scar tissue. In a patient who has had multiple laparotomy wounds, this is seldom the case and, in such a situation, we prefer to use a mass closure technique with a larger needle using a continuous 0 gauge monofilament absorbable suture. This technique is more likely to ensure fascial edge incorporation in the stitch. The assistant should follow the suture loosely so that one can achieve the best possible stitch-to-wound length ratio, aiming for at least a 4:1 suture-to-wound length ratio.

If one is clearing fat from the anterior aspect of the fascia to permit accurate visualisation of the fascial edge and accurate suture placement then it is important not to extend the dissection for more than is absolutely necessary. Try to avoid damaging the periumbilical perforators to minimise the risk of wound ischaemia in a re-operated abdomen, particularly if a stoma has been created at this operation, or previous operations, or there has been a previous transverse incision, as the inferior epigastric vessels may have been compromised and with them the lipocutaneous blood supply. In high-risk wounds, one should consider augmenting accurate surgical closure with a vacuum-assisted dressing. This would include patients at high risk of developing wound problems (e.g. emergency surgery, steroid usage, active infection, malnutrition, etc.).

HOW TO DEAL WITH A BURST ABDOMEN AFTER ABDOMINAL SURGERY

Whilst a burst abdomen usually means an urgent return to theatre, exactly how one deals with this problem will depend on the timing of the presentation, the well-being of the patient and the extent of the dehiscence and extrusion of abdominal contents. If a frail patient presents a week or more post-index laparotomy by virtue of a serous leak from the wound and clinical examination reveals that the fascia has only partially given way, and that the omentum has plugged the fascial defect and no bowel is exposed, it may be reasonable to manage conservatively without a return to theatre and to deal with the inevitable incisional hernia in due course. If, however, there is an early extrusion of the abdominal contents with bowel loops lying free in the superficial wound, then surgery is required. Prior to emergency return to theatre, every effort is made to protect the bowel loops and keep the bowel moist to reduce the risk of a subsequent enteric fistula. In theatre, the abdominal contents are returned to the abdominal cavity proper, below the fascia, and then one must close the fascia. Our personal preference is to base our technique on the quality and integrity of the fascia but most often will use a continuous absorbable 0 gauge monofilament suture with the highest possible suture-to-wound length ratio but vary the width of the bites from the edge of the fascia to try and prevent buttonholing through inevitably poor-quality tissues. The skin is closed with dermal and subcuticular sutures and then a vacuum dressing is applied in this high-risk wound group.

Alternative techniques of midline fascial closure such as the far-and-near Cardiff technique may be preferred by some surgeons after complete abdominal wound dehiscence or after laparostomy. This technique combines a standard mass closure (two-loop No. 1 PDS sutures) with a series of horizontal and two vertical mattress sutures within a single suture (1 nylon), theoretically distributing the load both along the incision length and across it. This is not our practice, nor do we advocate using tension sutures. We do not use mesh-mediated fascial traction in this group of patients, although this can be considered in certain situations.

CLOSING A TRANSVERSE INCISION

A transverse incision is closed in layers with a continuous slowly absorbable monofilament suture to close the peritoneum and posterior sheath as one layer, following which the anterior sheath is also closed with a continuous slowly absorbable monofilament suture. Scarpa's fascia is approximated with interrupted absorbable sutures, following which the skin is closed with a combination of dermal and subcuticular sutures.

CLOSING AN OPEN APPENDICECTOMY WOUND

Appendicectomy by an open incision has become less common due to a preference for a laparoscopic approach and, thus, experience with the open technique, in terms of both making the incision and closing it, has reduced. As a result, the irony is that an open technique may be used only in very difficult cases, often as part of a conversion. These are the very cases that are more likely to be complicated by a wound infection and prone to hernia formation. These patients then need careful attention to wound closure to try to prevent hernia formation. Lateral oblique hernias that occur after appendicectomy can be difficult to repair well, with problems in obtaining a durable result, and may need a major AWR approach, including posterior components separation with transversus abdominis release.

CLOSING AN OPEN MUSCLE-SPLITTING APPENDICECTOMY WOUND

The peritoneum is closed with a continuous absorbable monofilament suture. The three oblique muscles need to be identified individually. The transversus abdominus and internal obliques are approximated loosely with an absorbable suture. The external oblique is closed separately with a continuous absorbable suture more medially in the aponeurotic part and then, laterally, where there is a muscle component, an interrupted loose technique is used. It is important that, if the medial aspect of the anterior rectus sheath has been cut to aid exposure, this is closed separately with slowly absorbable monofilament sutures.

Scarpa's fascia is approximated separately as a finite entity and is often more prominent in the younger patient. The skin is approximated with dermal sutures and then subcuticular sutures or skin glue.

CLOSING A STOMA SITE AS A SINGLE PROCEDURE

It can be helpful to review a CT scan if the patient has had one since the stoma formation to check that the stoma was in fact fashioned within the confines of the rectus abdominis and is coming through the posterior and anterior sheaths. This is not always the case, and the stoma may have been sited more laterally through the abdominal obliques or through the linea semilunaris, which has been disrupted, possibly with a degree of denervation injury.

Reversal of a stoma as a sole procedure can be very challenging if it is an early reversal, if there has been a lot of inflammation such as peristomal Crohn's disease or if there has been mucocutaneous separation and scarring. Intestinal ischaemia can result in the bowel taking a parasitic blood supply from the skin and subcutaneous tissues. Optimal fascial closure techniques are uncertain. We have moved from interrupted figure-of-eight sutures with a large gauge suture to using a small-bites technique to close the anterior fascia alone without trying to incorporate the posterior sheath or muscle in an attempt to reduce SSOs, including incisional hernias. Recent prospective randomised trial data suggest a possible benefit from prophylactic biological mesh in preventing incisional hernia at the stoma site.

In this closure of an incision through a small hole, the key is identification of the anterior fascia, the anatomy of which will often have been distorted by some degree of parastomal hernia, which is extremely common. It is unclear whether the fascial component of a stoma wound with an associated hernia should be closed differently from a wound without a hernia. It is important to differentiate the fascia from scar tissue and hernia sac, and this often requires some sharp diathermy dissection to identify the edges. It is also important to identify the cephalad and caudad extent of the fascial defect. This is sometimes facilitated by making a very short longitudinal extension to the circum-stomal wound. A small-bites technique using 2/0 PDS with slip knots at each end is used for fascial approximation.

As regards the superficial wound closure at stoma sites, we do not close the skin but rather perform a subcuticular purse string to reduce the circular wound diameter by 50% and permit the wound to heal by secondary intention. There is level I randomised trial evidence in favour of purse-string closure of the superficial wound rather than primary skin closure in terms of reducing SSI. There is also some small cohort-based data to suggest a role for negative pressure wound therapy applied to these stoma closure wounds.

CLOSING A STOMA WOUND AS PART OF A LAPAROTOMY

Close the posterior sheath with a continuous slowly absorbable 2/0 monofilament suture before closing the laparotomy wound. Do not close the anterior fascia in the stoma wound until the laparotomy wound is closed, and then close the anterior fascia and do a subcuticular purse string as outlined previously.

MINIMALLY INVASIVE ACCESS TO THE ABDOMINAL WALL

Safe and effective access to the abdominal cavity is paramount to successful MIS. Insertion of laparoscopic or robotic ports into the abdominal wall should be completed in a manner that minimises the risk to intra-abdominal structures during insertion, provides a reliable pneumoperitoneum, optimises ergonomics, provides good views of intra-abdominal structures and, in the case of robotic surgery, minimises clashing of instruments either within or outside the abdominal cavity. A number of methods of insertion of the initial trocar have been popularised.

Open The open Hasson method of insertion of laparoscopic ports at the umbilicus has become the most commonly utilised method. This involves a supra- or infra-umbilical incision and identification of the umbilical stalk. Vertical traction on the umbilical stalk, using Littlewood forceps or a similar instrument, allows dissection of tissues off the umbilical stalk and delineation of the interface between the umbilical stalk and the linea alba. This is followed by vertical incision of the linea alba at this interface. A blunt surgical clip, such as Spencer Wells, is used to pierce the parietal peritoneum underlying this area and the port inserted under direct vision. Whilst the umbilicus is the most commonly employed site for this technique, the technique can be employed at other sites in the abdominal wall.

Needle insufflation The blind introduction of a Veress needle to the abdominal cavity was a favoured technique initially, often used in the peri-umbilical region; however, this has become less common owing to safety concerns surrounding the potential of inadvertent injury to underlying structures. Veress insufflation is now more commonly employed at ‘Palmer’s point’ in the left mid-clavicular line 2–3 cm below the costal margin, to minimise the risk of damage to underlying structures. Recently, Veress insufflation has experienced increasing popularity due to the growth of robotic abdominal surgery, which uses ports often not centred upon the umbilicus, making the open Hasson technique less popular for this type of surgery.

Optical trocar An optical trocar is a translucent laparoscopic trocar that allows the identification of the layers of the abdominal wall via a laparoscope as the trocar is driven through the abdominal wall. The direct introduction of an optical trocar may be less time consuming than the open technique and can facilitate camera port placement away from the umbilicus, but is associated with an increased risk of underlying injury. Most commonly, optical trocar use is combined with elevation of the abdominal wall using forceps or after the creation of a pneumoperitoneum using a Veress needle.

Specimen extraction site Some surgeons choose to begin minimally invasive operations with an open incision, which they intend to use for specimen extraction in the case of resectional surgery. This is often a Pfannenstiel or an off-midline transverse incision. Using a wound protector combined with a laparoscopic cap, an open incision can allow safe entry to the abdominal cavity with maintenance of an air-seal required for a pneumoperitoneum, and subsequent insertion of laparoscopic ports under vision.

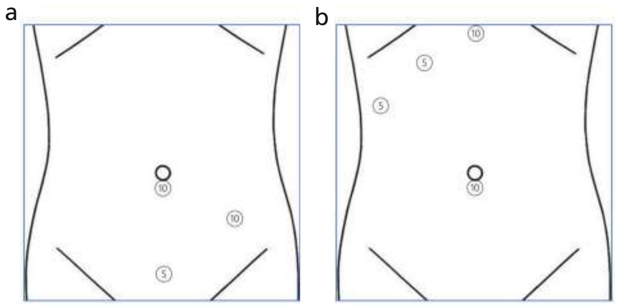
In each of these methods, once a pneumoperitoneum has been achieved, additional ports can be inserted under vision to minimise the risk of inadvertent injury.

PORT SELECTION AND PLACEMENT

In laparoscopic surgery, effective port placement and selection is an important factor in a successful operation. Laparoscopic ports come in a variety of sizes. However, the most commonly used are 5 mm, 10 mm, 11 mm and 12 mm. The combination of these sizes should be organised to allow good views, effective retraction and the introduction of necessary laparoscopic equipment.

Laparoscopes are available in 5 mm and 10 mm, with 10 mm laparoscopes most commonly used due to their superior image quality. These scopes will require a 10 mm port, often placed at the umbilicus. Some laparoscopic instruments require larger size ports, such as laparoscopic staplers or laparoscopic vascular ligation systems, and port positioning should be carefully considered to allow larger ports at the sites where such devices will be afforded optimal access to their target structures.

In addition to correct port selection, port placement is key. Ports should be placed in such a fashion as to allow optimal ergonomics. Ports should be



6.4 (a) Laparoscopic appendectomy port sites. (b) Laparoscopic cholecystectomy port sites. ⏎

triangulated with the laparoscope trocar placed 15–20 cm from the target organ and other trocars placed 7–10 cm on either side of this. Diagrams of commonly used port placement options for common operations are shown in Figure 6.4.

ROBOTIC PORTS

Multiple surgical robotic systems are now in use worldwide. Such systems have changed the approach to port placement that had become commonplace in laparoscopic surgery. Modern robotic systems are not solely based around the commonly used 5 and 10 mm ports employed in laparoscopic surgery, and port sizes can vary, with the most commonly used robotic system using 8 mm or 12 mm ports. Furthermore, port placement can differ significantly from the laparoscopic placement sites for an operation. However, this can differ depending upon the robot manufacturer. The most commonly utilised surgical robot requires port placement 15–20 cm away from the target organ. Ports are orientated in a straight line, orientated perpendicular to the target organ, with a minimum of 8 cm between ports; however, this approach is not universally adopted for use with other surgical robots. Central to robotic port placement is ensuring that robotic instruments and robotic arms avoid ‘clashing’, either externally or intra-abdominally, which can significantly hamper progress during a robotic operation, and care must be taken to allow adequate clearance between port sites.

PORT SITE CLOSURE

Whilst laparoscopic/robotic port sites are small incisions, care must be taken when closing them to limit the risk of hernia formation, which can occur either acutely in the early postoperative period causing early small bowel obstruction or at any point in the future. Whilst not universal, most laparoscopic surgeons will omit closing muscle and sheath for 5 mm ports due to the low risk of hernia formation, but will endeavour to close ports of 10 mm diameter or greater. This can be done with open or laparoscopic techniques. Ports of 10 mm diameter or greater can be accessed with retractors and the fascia grasped using forceps, allowing interrupted sutures to be inserted to the fascia using a strong, monofilament suture such as 0 PDS, often using a J-shaped needle. This can be somewhat challenging in patients with significant subcutaneous adiposity. Alternatively, sutures can be placed using a needle suture passer, under laparoscopic vision, which can be particularly helpful in obese patients.

Laparoscopic port sites can often be useful for the insertion of surgical drains at the end of an operation. Care must be taken to avoid placement of surgical drains through port sites 10 mm or greater, as this increases the risk of hernia formation, and 5 mm port sites should be favoured for this purpose.

EXTRAPERITONEAL MINIMALLY INVASIVE ACCESS

The majority of laparoscopic and robotic surgery is conducted with ports placed intraperitoneally; however, extraperitoneal access and development of the extraperitoneal plane can be performed. This is utilised in cases where retroperitoneal organs must be accessed and has also become a popular technique in hernia surgery. The totally extraperitoneal (TEP) technique for groin hernia repair involves the insertion of a laparoscopic trocar in the retrorectus space near the umbilicus by incision of the skin and anterior sheath and retracting the rectus abdominis laterally to allow insertion of a trocar into this space. The retrorectus space and extraperitoneal space can then be developed using a balloon trocar or blunt dissection with a laparoscope to facilitate further port placement. This access to the extraperitoneal space below the arcuate line provides excellent visualisation to the hernial orifices and epigastric vessels in the groin.

The TEP technique has been developed by Daes into the extended TEP (eTEP) approach, often beginning with access to the retrorectus space in the upper part of the abdomen by direct insertion of an optical trocar into the retrorectus space. This plane can be developed bilaterally to the entire retrorectus/extraperitoneal space permitting access to the entire linea alba. Such exposure can allow a Rives–Stoppa repair to be completed in a minimal-access fashion with placement of a retrorectus mesh. Development of this plane using the eTEP approach can also be the initial step in completion of a minimally invasive posterior components separation.

MANAGING THE OPEN ABDOMEN

In some operations, a decision must be made to intentionally not close the abdomen. This can be because either it is not possible to close the abdomen or it is unwise in the context of a critically ill patient or in the context of damage-control surgery. If this situation arises, a surgeon may be required to form a laparostomy. If one makes the decision for laparostomy formation, it is important to have a plan to achieve delayed abdominal wall closure. This is imperative, as laparostomy formation is associated with the formation of enterocutaneous and enteroatmospheric fistulae and with the formation of massive ventral hernias, which can be challenging to reconstruct in the future.

Laparostomy management

Once the decision is made to form a laparostomy in a patient, care must be taken to manage this appropriately. In doing so, the surgeon must adopt an approach that provides a protective covering for the viscera, minimises the risk of fistulation, minimises adhesion formation and optimises the chances of delayed primary closure of the abdomen in the ensuing days.

Previously described temporary abdominal closure techniques such as the Bogota bag technique are now not widely employed in high-income countries, owing to the widespread adoption of vacuum-assisted wound closure devices, which can be sourced as premade devices or improvised such as by the Op-Site sandwich technique. In situations where these devices are not available, the Bogota bag is still a safe and viable option. This technique involves suturing a sterilised intravenous fluid bag to either the fascia or the skin to temporarily cover the abdominal viscera. It is important to ensure that the closure is tension free to allow expansion of the intra-abdominal contents. Commercially available, pre-made vacuum-assisted devices incorporate a large sheet of plastic material that forms a protective barrier not only between the viscera and the atmosphere but also between the viscera and the parietal peritoneum of the abdominal wall, which reduces the formation of adhesions in this area, facilitating safe re-entry to the abdomen for further intervention or delayed primary closure. In addition to its protective role, vacuum-assisted therapy provides an element of medial tension on the fascial edges, limiting the tendency for the fascial edges to retract laterally, which makes delayed wound closure more difficult. Vacuum-assisted therapy also actively removes fluid from the abdominal cavity and promotes more effective and comfortable nursing of the patient when they return to the critical care unit.

A number of techniques are employed to allow delayed fascial closure of the laparostomy, with mesh-mediated fascial traction being the most commonly employed. This technique involves the insertion of the polypropylene sheet of a vacuum-assisted wound closure device as the initial step. Following this, a large medium- or heavyweight polypropylene mesh is sutured to the fascial edges of the laparostomy, covering the plastic sheet. Once this has been achieved, the middle of the polypropylene mesh is divided, leaving two pieces, one attached to each fascial edge. The two opposing pieces of polypropylene mesh are sutured together and the vacuum component of the vacuum dressing is applied. This manoeuvre prevents lateral retraction of the fascial edges initially and during sequential visits to theatre allows the two pieces of mesh to be sutured together with increasing tension, closing the distance between the fascial edges of the laparostomy. This process leads to a point at which the vacuum-assisted device and polypropylene mesh can be removed and the fascial edges closed.

Commercially available devices have become available that exert continued fascial traction on the edges of the laparostomy wound when the patient returns to the critical care unit. The tension that the device applies to the fascial edges can be adjusted without the need for re-suturing of a mesh or return to theatre, and so may be associated with a reduced time to fascial closure compared with traditional mesh-mediated fascial traction, as tensile forces can be maintained despite progressive medialisation of the fascial edges.

ABDOMINAL WALL HERNIAS

General considerations

In order to perform a durable hernia repair, one needs the most information possible about both the patient and the hernia. With regard to the patient, it is important to know what their priorities are and what they would consider a satisfactory outcome. This will include a discussion on their views about the use of mesh. Regardless of technique, optimised diabetic control with assessment of HbA1c along with smoking cessation for 4–6 weeks prior to surgery are important factors in reducing SSIs. It is also good practice to encourage micronutrient supplements preoperatively to aid wound healing and correct subclinical deficiencies in vitamin C, selenium and zinc, all of which are important in wound healing. If time permits, then weight reduction towards ideal body weight is advised and certainly one should try and get the patient’s body mass index (BMI) below 35 if possible. Physical conditioning and prehabilitation are also important preoperative factors, as are expectation management and accurate profiling of postoperative recovery. Chronic pain is a common problem in people who have large complex, or recurrent, hernias and this needs careful consideration and management.

APPLIED ANATOMY FROM CT SCANNING

CT scanning is a critical part of understanding abdominal wall anatomy and the applied anatomy relative to the surgical case in question. It is a fundamental requirement in advanced hernia practice. CT helps define anatomy and patho-anatomy and excludes concomitant unexpected pathology that, if undiscovered, might make hernia surgery inappropriate or extremely difficult. CT also permits the detection of other hernia defects that are not clinically apparent, which would otherwise come to light as 'recurrence' in the postoperative period. Most of these other defects can be seen by CT scanning, as can occult intra-abdominal pathology that might alter the surgical approach or timing.

The width of both recti relative to the width of the diastasis of a ventral hernia is a useful guide in determining ease of reconstruction of the linea alba during an AWR approach. This can be determined preoperatively and act as a guide on the need for adjunctive preoperative Botox and/or components separation. In a patient with a ventral hernia, the degree to which Botox may help re-approximate the midline might be guided by the extent to which the oblique muscles have 'bunched up' more laterally.

CT scanning reveals the width of the diastasis at different levels in the abdomen. There is a tendency to concentrate on the mid abdomen where the maximal width may be, but it is often the epigastric diastasis width that determines whether components separation is needed and whether it will be possible to reconstruct the linea alba in this portion of the midline.

CT is very helpful in assessing lateral hernias. CT helps to determine the degree of denervation injury as opposed to actual herniation and, in terms of a durable repair, is very helpful at looking for the posterior extent of the defect and whether there is an intercostal component. In both ventral and lateral hernias, CT allows you to determine the extent of any loss of domain.

UMBILICAL AND EPIGASTRIC HERNIAS

Symptomatic umbilical and epigastric hernias should be repaired if clinically appropriate. Sutured repair can be considered in shared decision-making and is appropriate for small hernia defects less than 1 cm in diameter. The use of mesh reduces recurrence without significantly increasing the rate of SSI or postoperative pain. Ideally, a flat polypropylene mesh should be placed preperitoneally with a circumferential 3 cm underlap beyond the fascial neck of the hernia and the defect sutured closed.

A sublay mesh repair is used for repair of umbilical and epigastric hernias to reduce the recurrence rate. Many different three-dimensional meshes are available, but the preferred approach is a flat polypropylene mesh, placed in a preperitoneal pocket, with subsequent closure of the fascial defect. When repairing epigastric and umbilical hernias as an emergency, all factors need to be taken into consideration and the approach tailored accordingly, but mesh may be used in a clean or a clean-contaminated field.

In practice, to repair an umbilical hernia, a short transverse incision is made either just above or below the umbilicus, depending on the main aspect of the hernia sac bulge. The skin is lifted off the sac, which is dissected out, and then the sac is reduced below the fascial defect. A subfascial space is then created, below the defect, by blunt and sharp dissection to create a pocket for the flat mesh to lie in. The mesh is then inserted and encouraged to lie flat, after which the fascia is closed with a monofilament suture.

If performing a suture repair of a smaller umbilical hernia, the initial dissection is the same but the defect is closed with one or two interrupted figure-of-eight non-absorbable sutures with the knots on the inside.

SPIGELIAN HERNIAS

Classical Spigelian hernias occur as protrusions through defects in the aponeurosis of the transversus abdominus muscle limited by the linea semilunaris laterally and the lateral edge of the rectus muscle medially. They are interstitial hernias, meaning that the defect in the abdominal wall is incomplete and does not involve all muscle layers. The fascial defect involves the transversalis fascia, the transversus abdominis and the internal oblique, but not the external oblique, which is intact and overlies the hernia sac. This can make Spigelian hernias difficult to diagnose, as the swelling can be very diffuse or imperceptible clinically. Axial scanning may help but, sometimes, laparoscopy is needed to accurately make, or refute, the diagnosis. This can then be followed by a laparoscopic repair or a hybrid laparoscopic and open repair in which the defect is located and marked laparoscopically permitting a small incision over this point with division of the external oblique to expose the sac, which is then reduced. A mesh is placed below the transversus abdominus and then the defect in the transversus and internal oblique is closed, as is the incised external oblique. Slowly absorbable monofilament sutures are used to close the layers.

LUMBAR HERNIAS

A primary lumbar hernia is a defect in the lumbar region, which is bounded by the 12th rib above, the iliac crest below, the free border of the external oblique muscles anteriorly and the vertebral column posteriorly. These rare hernias may require referral to a specialist centre with experience in posterolateral incisional hernias and may possibly be suitable for a robotic, and open hybrid transversus abdominus release, mesh repair approach.

INCISIONAL HERNIAS

There are some general principles which have emerged from practice that have been summarised in recent guidance. The important modifiable risk factors are high BMI, poorly controlled diabetes and smoking, and it is good practice to recommend preoptimisation and prehabilitation with weight loss, diabetic control, smoking cessation and improved cardiopulmonary performance. As in other hernia surgery, it is also important to optimise micronutrients to aid wound healing and repair. If hernias are very symptomatic or a cause of small bowel obstruction or if the trajectory of hernia development is such that it may become more and more complex to repair, then it may be prudent to proceed with surgery without perfect optimisation. Most surgeons will offer surgery to someone with a BMI up to 35.

LOSS OF DOMAIN

This is an important and often misunderstood concept. Firstly, it has nothing to do with the size of the hernia defect or loss of tissue in the abdominal wall. It refers to the fact that, as intraperitoneal contents are extruded out into the hernia sac, the abdominal cavity proper, below the fascial boundaries, shrinks by the commensurate volume. The intra-abdominal contents that have been extruded thus lose their right of domicile (i.e. their right of domain). This is related to reducibility. If a hernia, regardless of size, always reduces when the patient lies down, there is no loss of domain. There can be a small defect and a big hernia sac or a big defect and a big hernia sac. This is not the issue. The issue is whether the sac empties its contents back into the abdominal cavity proper. This is important because if a hernia with significant loss of domain is repaired by traditional techniques, then there may be a critical increase in intra-abdominal pressure postoperatively. This can cause respiratory, renal and multiorgan dysfunction as part of an abdominal compartment syndrome.

MIDLINE INCISIONAL HERNIAS

These are common and, unfortunately, failure after repair is also common. The fundamental decision is whether or not one should try a standard preperitoneal mesh repair or a more advanced technique such as a Rives–Stoppa repair or some other AWR approach.

LATERAL INCISIONAL HERNIAS

These are usually after urological surgery or open appendicectomy. CT scanning is very useful in determining the patho-anatomy. Key factors are the posterior extent of the defect, the degree of associated denervation and/or rectus muscle involvement, the degree of tissue loss, whether the hernia is interstitial with an intact external oblique and whether there is loss of domain. Local repair is often unsuccessful and leads to recurrence with further complexity, and a philosophy of ‘straight to AWR’ is often appropriate. Our technique of choice is usually a transversus abdominus release on the hernia side with a Rives–Stoppa retrorectus dissection only on the contralateral side. We use a large polypropylene mesh extending up under the diaphragm and down to Cooper’s ligaments and extending out posterolaterally onto the psoas muscles. It is possible to perform some of these cases by an MIS approach or a hybrid open/MIS approach but, in general terms, one might consider lateral or oblique hernias as cases to consider referring to a specialist centre.

Colorectal surgeons will regularly encounter a variant of a lateral hernia in patients with a stoma who have a parastomal hernia and a midline incisional hernia. CT scanning is extremely useful here, as the hernia anatomy can be almost impossible to determine clinically. As regards the parastomal component, the key is whether the linea semilunaris has been violated or whether the hernia lies completely within the rectus sheath. It can also be the case that, in very large hernias of this sort, the rectus muscle has been widely splayed and the epigastric vessels damaged, all of which add to complexity.

DIASTASIS OF THE RECTI MUSCLES

The linea alba, the midline fusion or aponeurosis created by the coming together of the fascia around each of the rectus abdominus muscles, can become stretched. The normal range is 0–2 cm. Rectus diastasis is defined as a separation of more than 2 cm between the recti. Patients can be concerned that they have a bulge that they think is a hernia or they have been told is a hernia. It is not a hernia and is a fascial widening and weakening with an associated bulge. There is no fascial defect and there is no risk of incarceration or strangulation. More often than not, the patient is best treated by reassurance and exercise with physiotherapy and muscle strengthening in the first instance. A very large rectus diastasis can cause the same complaints as a hernia, however, and may be appropriate for surgery as a first-line therapy. A minority of patients can have a severe bulge that is functionally debilitating and is almost behaving like a hernia.

Diastasis recti can also occur with hernias, either epigastric or umbilical, or both. In this situation, the patient may not complain of the diastasis but it is seen on CT scan. Simple local repair of these hernias in this context is more likely to lead to recurrence, and our practice is to discuss an AWR approach with these patients and offer them a choice between a Rives–Stoppa-type full-length midline repair with mesh or a local preperitoneal mesh repair. The guidance is for a mesh-based repair when rectus diastasis is associated with a midline hernia.

MESH SELECTION AND PLACEMENT

A key component of a hernia repair is appropriate selection of a mesh material and placing this in the appropriate plane in the abdominal wall. There is no single, correct choice in this regard; instead, the surgeon must tailor their choice of mesh material and placement to the patient, the patient's wishes, the clinical situation, the patient's age, the presence of contamination and the potential for further surgery.

Broadly, mesh material is synthetic, biological or biosynthetic. Meshes can be absorbable or non-absorbable. Synthetic meshes are commonly made of polypropylene, polyester or polytetrafluoroethylene and are associated with the lowest rates of hernia recurrence and are widely available and cost-effective. Whilst this is the case, a number of factors may necessitate an alternative choice. In cases where contamination is present, implantation of a permanent mesh may precipitate a serious and long-standing mesh infection, which can be difficult to treat, necessitating the use of an alternative option. It is very undesirable for viscera to come into contact with surgical mesh, particularly with uncoated synthetic mesh. If this is a risk, bioabsorbable or biological meshes may be selected.

In addition to selecting the appropriate mesh for a hernia repair, it is key to place this in the correct plane in the abdominal wall. Mesh can be placed in intraperitoneal, preperitoneal or retromuscular positions or can be positioned as 'inlay' or 'onlay' repairs. In an 'inlay' repair, mesh is sutured to the edges of the fascial defect without myofascial approximation, and an 'onlay' repair is where mesh is placed on top of the fascia. Whilst utilised in the past, neither of these techniques would be advocated currently and are associated with high rates of recurrence.

Intraperitoneal mesh placement has become popular with the use of laparoscopic intraperitoneal onlay mesh repairs, where a mesh is tacked laparoscopically in an intraperitoneal position to the abdominal wall, over a hernia defect. The mesh placed in an intraperitoneal position must be coated with a non-adhesive coating to prevent the formation of adhesions of bowel to the mesh.

Optimally, mesh placement should be in the preperitoneal or retromuscular positions, affording the lowest chance of recurrence whilst the peritoneum or posterior sheath protects the viscera from coming into contact with the mesh. The retromuscular plane is where mesh is placed in a Rives–Stoppa–Wantz repair. In some repairs, the preperitoneal and retromuscular planes can become continuous, as in the case of a transversus abdominis release, where the retromuscular plane is accessed behind the rectus abdominis muscles but is switched to the preperitoneal plane behind the transversus abdominis and transversalis fascia.

ABDOMINAL WALL RECONSTRUCTION

This term mostly applies to advanced hernia techniques for complex hernias where some form of myofascial release is required to approximate native tissues to close the hernia defect, be that in the midline or laterally, with the aim of repairing the defect and maintaining abdominal wall function. The concepts evolved from plastic surgery practice, where previously large abdominal wall defects may have been covered by transposed myocutaneous flaps such as a tensor fascia lata flap. Whilst providing cover for the defect, they were functionally suboptimal. AWR techniques involve cutting, or releasing, some part of the lateral three-part oblique myofascial unit to permit medialisation of the recti or placement of a mesh deep to the entire abdominal wall muscle block. These releases are referred to as components separation. When the anterior, most external oblique muscle is cut and released, the procedure is referred to as anterior components separation. This is useful for medialisation of the recti in midline defects. When the transversus abdominis muscle is cut, then the procedure is referred to as a posterior components separation. This can also be used to facilitate midline closure and retromuscular mesh placement, but the technique is most useful for lateral hernias that cannot be repaired by anterior components separation. One must never do both anterior and posterior releases. The fundamental initial procedure that must be mastered is the Rives–Stoppa retrorectus dissection. One of the two different components separation techniques may then be added as appropriate, but anterior and posterior components separation techniques should not be used at the same time.

RIVES–STOPPA–WANTZ REPAIR

The classical dissection is to enter the peritoneal cavity via a midline incision and then, having released adhesions between bowel loops and the parietal peritoneum, to identify the medial edge of the rectus fascia on each side. An incision is then made in the posterior rectus sheath 1 cm lateral to this medial edge, and this is extended superiorly and inferiorly from costal margin to pubis. The rectus muscle is dissected off the front of the posterior rectus sheath out as far as the linea semilunaris, which is identified by the combination of vessels and nerves entering the rectus sheath at the lateral extent of the rectus muscle. This is done from behind the xiphisternum down into the cave of Retzius to identify Cooper's ligaments. A mesh is then placed in this space and secured superiorly to the xiphisternum and inferiorly to Cooper's ligaments. Following mesh placement, the linea alba is recreated by approximating the two halves of the anterior midline fascia. We perform this closure with a small-bites closure technique.

ANTERIOR COMPONENTS SEPARATION

The classical approach follows a retrorectus dissection, as above. A lipocutaneous paddle of skin and subcutaneous fat is then dissected off the front of each rectus sheath out to its lateral border. The lateral edge of the rectus sheath is palpated and then an incision is made in the external oblique aponeurosis 1 cm lateral to the edge of the rectus sheath. A fat pad is encountered and then this plane is extended cephalad, and caudally, from costal margin to inguinal ligament. This is repeated on the contralateral side. Anterior components separation gives excellent medialisation in ventral hernia surgery, but has drawbacks related to the need for an extensive lipocutaneous dissection with attendant potential wound complications due to interruption of perforator blood vessels, its lack of applicability for lateral hernias and the fact that one has created a lateral fascial defect that cannot have mesh placed behind it (although can have a mesh insert placed within it) and is therefore prone to postoperative bulging.

POSTERIOR COMPONENTS SEPARATION

In this technique, it is the posterior, most oblique muscle that is released. The transversus abdominus muscle is divided behind the rectus abdominus after it has been exposed by retrorectus dissection. The muscle is divided along its length from costal margin to the arcuate line. The transversalis fascia is exposed, and a plane is dissected between it and the back of the transversus abdominus muscle fibres. This plane permits access around to the psoas muscles laterally and right up under the diaphragm superiorly. Inferiorly, there is no transversus abdominus muscle behind the rectus sheath, below the arcuate line (the lower free edge of the transversus abdominis is the arcuate line), so the dissection is as for Rives–Stoppa and descends into the retropubic space to Cooper's ligaments. It produces an excellent posterior medialisation, and the plane used is what makes it so suitable for off-midline hernias and large ventral hernias. After completion of this extensive dissection, the visceral sac is reconstituted and a very large mesh is laid into this extraperitoneal retromuscular plane. The midline fascia is closed with a small-bites technique, reconstituting the linea alba. This technique takes understanding, education and experience, but ultimately does provide a very good-quality repair that is durable in the long term and not prone to many of the short-term wound complications such as seroma and SSI that are seen with other techniques.

ABDOMINAL WALL ADJUNCTS

ABDOMINAL WALL BOTULINUM TOXIN INJECTION

Patients with large ventral hernias often experience lateralisation of the fascial edges and large defects as a consequence. In this situation, it is often not possible to bring the fascial edges together for a repair in a tension-free manner. Preoperative injection of botulinum toxin to the abdominal oblique muscles can provide muscular relaxation of the lateral abdominal muscles and facilitate myofascial closure in the midline, thereby improving rates of success for hernia repair.

In large hernias, components separation may be required to achieve fascial approximation. This can be at the cost of surgical time, increased surgical and physiological insult to the patient, division of core abdominal muscles, and pain. Botulinum toxin injection can allow 'downstaging' of a hernia repair, allowing patients who previously may have been subjected to components separation to be treated with a Rives–Stoppa repair alone.

Botulinum toxin injection is usually performed 3–6 weeks preoperatively, under local anaesthetic. Botulinum toxin continues to take effect for up to 3 months, allowing a therapeutic effect to take place both preoperatively and in the postoperative healing phase.

INTRAOPERATIVE FASCIAL TRACTION

Commercially available devices have been developed, which are designed to apply a constant tensile force to fascial edges during surgery to promote fascial approximation in the midline. Strong sutures are inserted to the fascia and connected to such devices, and a constant, measurable force is applied to the fascial edges over 30 minutes or so following a Rives–Stoppa dissection. This can have the effect of improved medialisation of fascial edges and a potential downstaging effect, allowing patients who may have required components separation to be treated with a Rives–Stoppa repair.

PROGRESSIVE PREOPERATIVE PNEUMOPERITONEUM

This is a preoperative adjunctive technique that is used in patients with marked loss of domain. It aims to try and stretch up the peritoneal cavity preoperatively to recreate a place, or domain, for the intraperitoneal contents residing in the hernia sac to be returned to the abdominal cavity without creating excess intra-abdominal pressure and abdominal compartment syndrome. An intraperitoneal catheter is placed and air is delivered into the peritoneal cavity slowly and incrementally over a week to stretch the abdominal cavity.

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7

General techniques in abdominal and gastrointestinal surgery

Rajat Raghunath

PROBLEMS OF ACCESS

In many situations, an operation is technically demanding because of difficulties of access, and this is particularly so in intra-abdominal surgery. Accessing certain areas of the abdomen requires specialised techniques and manoeuvres.

ABDOMINAL WALL ACCESS

The choice of abdominal incision or the position of laparoscopic ports is important. An inadequate incision is the most common cause of operative difficulty in open surgery. The abdominal muscles must be relaxed, both to reduce intra-abdominal pressure and to allow retraction of the abdominal wall. A self-retaining retractor is useful in major intra-abdominal surgery, as it frees the assistant for more precise and dynamic retraction in the area of dissection (Figure 7.1). A self-retaining retractor may make access to the lateral aspects of the anterior abdominal wall more difficult, however, and care should be taken to release any adhesions in this area before the retractor is positioned. Traditionally, the wound edges are protected from the retractor by large swabs but, more importantly, care must be taken not to catch a loop of small bowel. It is also easy to damage the abdominal or chest wall skin in the ratchet mechanism of a retractor.

ADHESIONS

Intraperitoneal adhesions may severely limit access within the abdomen. Thus, the release of these adhesions is often necessary before the planned surgery can proceed, and this may greatly increase the duration of an operation.[1] Adhesions are commonly the result of previous surgery, but adhesions may also follow an intraperitoneal infective process or closed blunt trauma. Small bowel adhesions to the anterior abdominal wall beneath an old scar are particularly dangerous, as it is easy to damage the bowel on the initial entry into the peritoneal cavity. Small bowel adhesions in the pelvis, to the site of previous surgery or pelvic infection, can also be difficult to release safely. Gentle traction will usually show the plane that requires division, either between the bowel loops or between the bowel and the abdominal wall. Adhesions between loops of the small bowel that are causing folds rather than kinks may be safely left undisturbed. Band adhesions, around which bowel loops could twist, should be divided even if division is not required for access.

DISSECTION

Much of the dissection within the abdomen consists of finding developmental areolar planes or the planes between adhesions. During dissection, the tissues must be held on stretch and the areolar tissue is divided as described in Chapter 1. Blunt dissection may result in tears in the bowel, liver or spleen and should be avoided as much as possible. Blunt dissection is also more likely to tear fine structures such as autonomic nerves lying adjacent to the planes of dissection. Sharp dissection may be carried out with scissors, a scalpel or diathermy. Diathermy has the advantage of reducing minor bleeding, but also has a greater potential for damage, especially in the hands of the inexperienced, and may also cause thermal damage to a structure that initially displays no visible injury. It is therefore safer to use sharp dissection with scissors when dissecting close to the bowel wall, a major vessel or a ureter.

Laparoscopic dissection is performed by holding tissue on stretch and dividing areolar planes in

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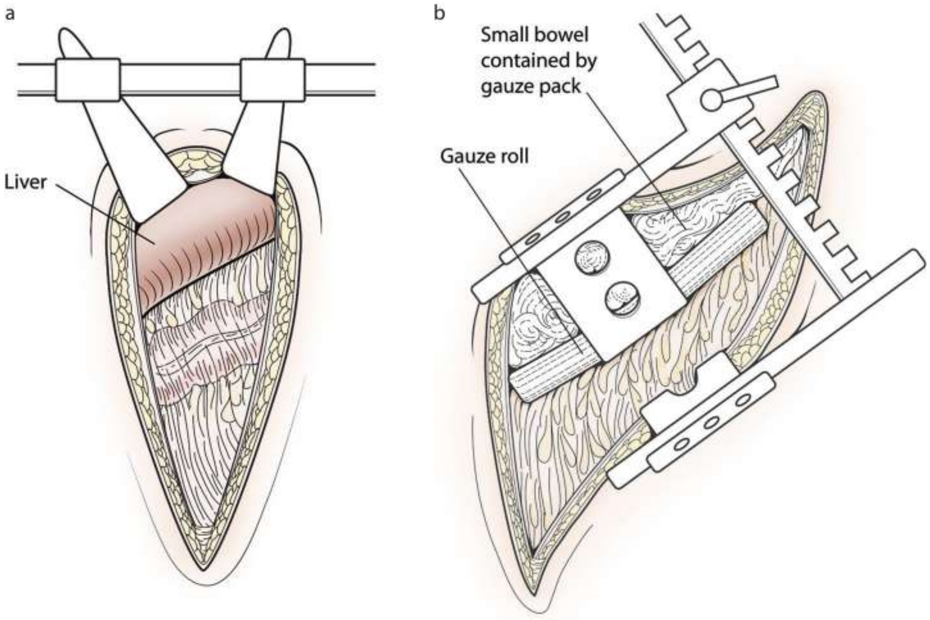


7.1 (a) Mechanical fixed retraction to a horizontal bar attached to the operating table lifts the costal margin upwards and cranially, increasing subdiaphragmatic access. (b) The deep self-retaining Finochietto retractor is holding the wound edges apart and is also holding the small bowel out of the pelvis. The small bowel has been wrapped in a large gauze pack, and a gauze roll has been placed along the left side of the mesenteric root. ⏎

a similar fashion to open surgery. A variety of blunt graspers have been designed for the retraction of tissue. A monopolar diathermy hook and scissors are the standard instruments for dissection. Alternatively, an ultrasonic dissector and coagulator can be used. Meticulous haemostasis is essential or visualisation rapidly deteriorates. Irrigation of the surgical field will clear small adherent blood clots, but irrigation fluid will then pool in dependent areas of the intraperitoneal space and can be challenging to aspirate.

If an injury to the bowel occurs during dissection, the segment should be examined carefully for any mucosal breach that will require repair. A seromuscular tear with thin intact mucosa is better supported with a partial-thickness seromuscular suture. Any injury to the bowel must be repaired with seromuscular sutures, usually in a direction perpendicular to the direction of the bowel. This is to prevent strictures of the small bowel in those with long serosal injuries. If any repair is deemed advisable, it is better to do it immediately, as it may be subsequently overlooked. Small bowel injury incurred at laparoscopy is easy to miss, as it may occur to a loop outside the view of the laparoscope and the raised intra-abdominal pressure may limit, or prevent, contents from escaping into the peritoneal cavity. Laparoscopic suture repair of small bowel injuries, or seromuscular tears, can be carried out using the same principles as open surgery, provided appropriate expertise is available. However, in some cases, conversion may be necessary to inspect and repair the small bowel.

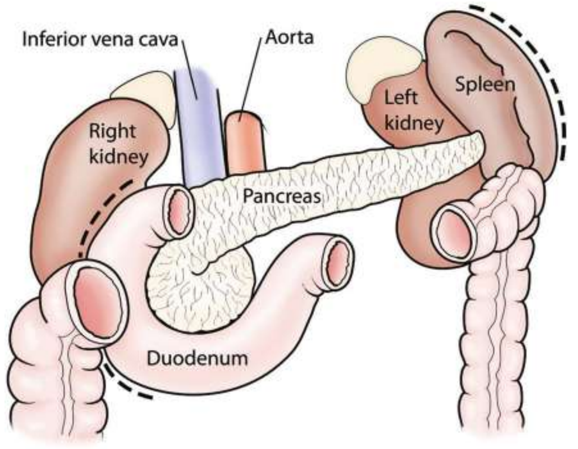
MOBILISATION OF VISCERA

Even in the absence of adhesions, access to all intra-abdominal viscera is not possible immediately on entering the peritoneal cavity. For example, the stomach, although fully covered in peritoneum, has an inaccessible posterior wall until entry has been gained into the lesser sac. Posteriorly, fully and partially, retroperitoneal structures lie in layers, and access to the more posterior structures must follow mobilisation of those lying anteriorly. There are three retroperitoneal areolar planes in which the surgeon can dissect in order to achieve this mobilisation. The first plane is behind the colon and in front of the duodenum. The second plane is behind the duodenum, pancreas and spleen, but in front of the kidneys, ureters and gonadal vessels. The third plane is behind the kidneys. The anatomy of the posterior abdominal planes and of the lesser sac and the concept of discrete retroperitoneal mesenteries can all be appreciated more readily from an embryological viewpoint.

SURGICAL EMBRYOLOGY OF THE ABDOMEN

Access within the abdomen is complicated by the intrauterine folding of the gastrointestinal tract, and therefore some understanding of abdominal embryology is essential for the surgeon.[2] In early intrauterine life, the entire gastrointestinal tract is a simple tube that is suspended from a midline dorsal mesentery. The blood supply is from the three midline visceral arteries to the foregut, midgut and hindgut. These persist in adult life as the coeliac axis, the superior mesenteric artery and the inferior mesenteric artery, all arising in the midline from the anterior surface of the aorta.

The small bowel persists from early embryonic life into adult life on a mesentery orientated approximately in the midline. However, the large bowel rotates in an anticlockwise direction, and the mesenteries of the ascending and descending colon then merge with the retroperitoneal tissue. The apposing two layers of peritoneum in contact are absorbed. It is relatively easy to appreciate this arrangement, as there is an areolar plane, which can be dissected with precision between the 'mesentery' of the ascending or descending colon and the truly retroperitoneal structures. If the ascending or descending colon is lifted forwards, a white line is visible on the peritoneum a few centimetres lateral to the colon. The areolar plane is entered by division of the peritoneum along this line, and the incision is continued around the colonic flexures. Access to the splenic flexure may be difficult, as it lies higher and deeper than the hepatic flexure and is attached to the diaphragm by a peritoneal fold, the phrenicocolic ligament. Excessive traction must be avoided or adhesions between the colon and the lower pole of the spleen may be disrupted, with resultant splenic capsular tears. Once the areolar plane behind the colon has been entered, it can be followed to the midline, and the colon is once again on its original midline mesentery. This is an important mobilisation manoeuvre and is the first step in an open radical hemicolectomy. It also allows operative access to the more posterior retroperitoneal structures. This first posterior plane is relatively easy to follow and, when difficulty is encountered, the surgeon has usually strayed too far posteriorly. The second part of the duodenum and the pancreatic head are thus vulnerable to injury during a right colon mobilisation, as are the duodenojejunal flexure and body of the pancreas during a left colon mobilisation (Figure 7.2).

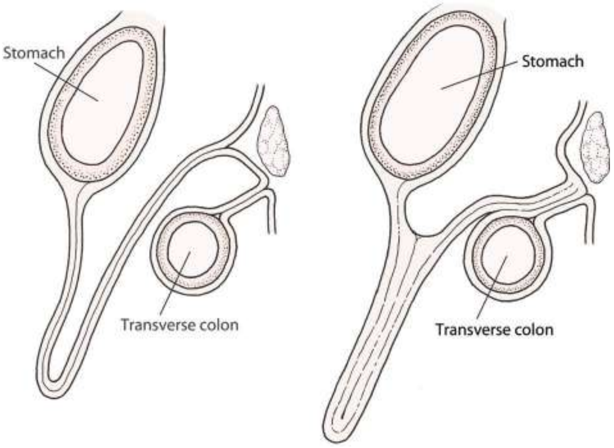


7.2 The embryological folding of the gut produces layers of mainly retroperitoneal organs, which can be separated along areolar planes. The anterior layer consists of the colon. The middle layer, consisting of the pancreas, duodenum and spleen, can be mobilised forwards by peritoneal incisions in the positions marked by the dotted lines. The posterior layer is made up of the kidneys, adrenals, aorta and vena cava. ⏎

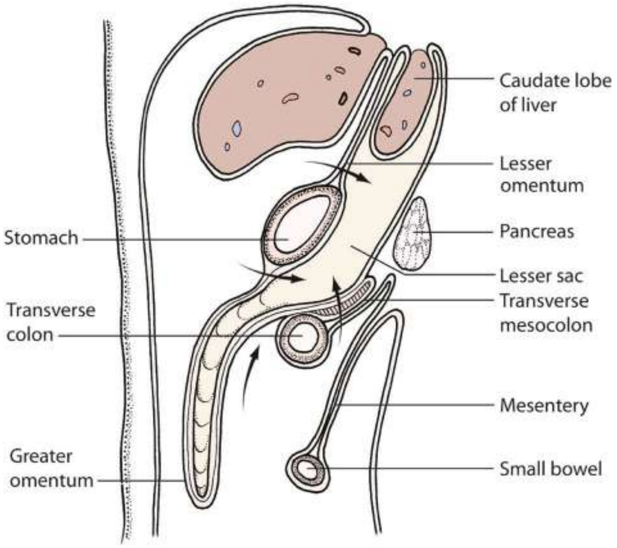
In the *pelvis*, a similar merging of tissue occurs between the mesorectum and the tissue of the pelvic wall. Again, there is a discrete plane of areolar tissue between the structures of the hindgut and the other structures in the pelvis. Fusion of the peritoneum in the depths of the rectovaginal or rectovesical pouch forms Denonvilliers' fascia, which is an important anatomical landmark in radical surgery of the rectum.

In the *upper abdomen*, the developmental rotation of the foregut is more complicated (Figure 7.3). Subsequent fusion of folds also complicates the anatomy around the transverse colon. The stomach originates as a dilatation of the foregut, with a dorsal and ventral mesentery. The dorsal aspect of the stomach grows more rapidly than the ventral aspect, forcing the distal stomach and duodenum upwards and to the right. The ventral mesentery becomes the lesser omentum and the dorsal mesentery the greater omentum. The duodenum also rotates to the right, and its right side loses its peritoneal covering as it fuses with the retroperitoneal tissue. There is a plane here that can be developed in the manoeuvre entitled 'Kocherisation of the duodenum'. An incision of the peritoneum outside the lateral border of the second part of the duodenum allows the duodenum and the head of the pancreas to be lifted forwards off the right kidney and inferior vena cava (IVC). The equivalent plane on the left is behind the spleen and tail of the pancreas. It is entered by division of the peritoneum lateral to the spleen (see Figure 7.2); this is the second posterior plane.

The adult anatomy of the upper gastrointestinal tract is shown in Figure 7.4. The *lesser sac* forms behind the stomach as it rotates, the anterior wall of the sac being composed mainly of the posterior wall



7.3 The developmental rotation and differential growth of the gut results in complicated upper abdominal anatomy. The greater omentum with the transverse colon effectively divides the abdomen into a supracolic and an infracolic compartment. ⏎



7.4 A diagrammatic sagittal section through the abdomen to show the disposition of the omentum and lesser sac. Arrows indicate routes of access into the lesser sac. ⏎

(the original right wall) of the stomach. It is in communication with the rest of the peritoneal cavity – the *greater sac* – but, due to differential growth, only by the small communication deep to the free edge of the lesser omentum. Lesser sac access is necessary for many upper gastrointestinal and hepatobiliary operations. The natural communication between the greater and lesser sacs cannot be enlarged, as the common bile duct, portal vein and hepatic artery run in the free edge of the lesser omentum, and the other boundaries of the channel are the IVC, the duodenum and the liver. The lesser sac may be entered through the lesser omentum away from the structures in the free edge, but access is limited. Entry below the greater curve of the stomach, through the gastrocolic part of the greater omentum, is satisfactory, but multiple ligations of gastric or omental branches of the gastroepiploic arcade are required, and devascularisation of the omentum may occur. Access through the transverse mesocolon risks injury to middle colic vessels, although a relatively avascular window to the left of these vessels can be utilised. The most extensive access can be obtained by separating the natural plane between the greater omentum and the anterior surface of the transverse colon. Once the plane has been identified, it can be followed to the right and left for a considerable distance, providing extensive access to the lesser sac. Only occasional small vessels cross the plane and require ligation. This plane is continuous around the colonic flexures with the plane that is developed to mobilise the ascending and descending colon.

Access to major vessels for vascular control is more fully addressed in Chapter 18. In general, however, the infrarenal aorta may be approached by swinging the transverse colon upwards and the small bowel to the patient's right. The posterior peritoneum is opened to the left of the fourth part of the duodenum. The IVC is exposed by Kocherisation of the duodenum, but access to the intrahepatic IVC requires full mobilisation of the right half of the liver. The third posterior plane behind the kidneys may be valuable for access to the posterior aspect of the intra-abdominal aorta or IVC.

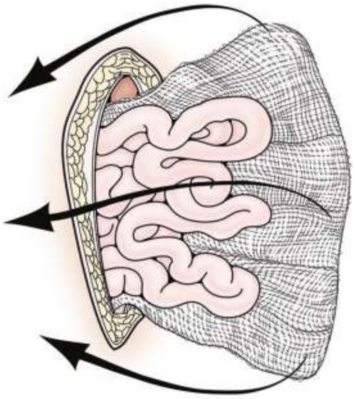
RETRACTION OF INTRA-ABDOMINAL VISCERA

Mobile bowel and other intra-abdominal viscera may have to be held out of the operative field to allow access and dissection in the area of interest. Distended obstructed bowel may impede access for safe dissection, and bowel deflation may be necessary early in a laparotomy, although, when a resection is planned, it can often be deferred and undertaken when the bowel is opened at the time of the resection.

Deflation of the bowel

Gastric deflation can be achieved using nasogastric tube aspiration, and jejunal contents can be 'milked' back into the stomach, from where they can also be aspirated (see Figure 13.8). The small bowel can also be deflated by the introduction of a needle, attached to suction, obliquely through the wall of the distended bowel. This technique, while excellent for gas or thin fluids, is unsuitable for thicker contents. Alternatively, the whole sucker is introduced through a small enterotomy into the bowel lumen. Before making the incision, a purse-string suture should be placed, which can be tightened immediately on introduction of the sucker to prevent leakage. After removal of the sucker, the suture is tightened and tied to close the enterotomy. This is a safer technique in the small bowel than in the colon. An obstructed distended colon has solid matter, which blocks suction tubing, and the only satisfactory solution may be *on-table lavage*, which is described in Chapter 13.

Fixed and handheld retractors are the main methods by which the operative field is displayed in open surgery. Gravity can also be utilised to increase potential spaces, for example by tilting the operating table head-up when working between the diaphragm and the liver or head-down to tip the small bowel out of the pelvis. The mobile bowel can be delivered outside the abdomen and placed in a bowel bag or warm wet packs, which reduces fluid loss from the surface. Whenever the bowel is outside the abdomen, care must be taken to avoid twisting or tension on the mesentery. However, cooling is still inevitable, and postoperative ileus may be less of a problem if the bowel can be 'packed away' within the abdomen. For example, if a left hemicolectomy is planned, the small bowel is delivered externally over the right abdominal wall. A large pack soaked in saline is then tucked into the mesenteric root from the left and the small bowel swung back on top of it. The remainder of the pack is then folded over the small bowel and used to retain it under the right side of the abdominal incision (Figure 7.5). A 20 cm (8 inch) gauze roll can then be placed to the left of the wrapped bowel, along the mesenteric root, and a deep self-retaining wound retractor opened so that the blade on the right wound edge pushes on the roll and the small bowel is held securely within the right half of the abdomen (see Figure 7.1b).



7.5 A large pack is tucked into the left side of the mesenteric root. It is folded over the small bowel, which can then be retained in the right half of the abdomen by the method shown in Figure 7.1b. ⏎

In laparoscopic surgery, the assistant usually has only one instrument available with which to retract, and much greater use is made of gravity to assist in vision and access. Additional retraction may be provided by fixed retractors inserted through the abdominal wall, often used to retract the liver in upper abdominal surgery. Alternatively, a suture with a straight needle can be passed through the abdominal wall from outside and through a structure such as the uterus before being passed back through the abdominal wall, where it can be used to retract the uterus during pelvic surgery.

REMOVAL OF DEBRIS AND BLOOD, FLUID AND SMOKE OF DIATHERMY

These must be removed from the operative field so that a clear view is maintained. Mechanical suction is satisfactory, except when there is solid matter. The suction end may have a single terminal opening, allowing accurate clearance of a defined area. A clear view of the sucker tip is essential because, if the single suction hole is occluded against tissue, damage can occur as the tissue is sucked into the device. Alternatively, a guard with multiple holes is screwed over the sucker. This is a safer instrument because, if one hole is occluded against the bowel wall, the remaining open channels continue to draw in fluid or air. This prevents the suction from drawing in tissue. It is therefore safe to pass a guarded sucker amongst small bowel loops to aspirate fluid or blood. Gentleness is still essential to avoid injury, but the surgeon does not need to be able to see the end of the instrument.

Blood clots and solid faecal material will block a sucker, and it is preferable to remove them with a swab.

Swab count

In intra-abdominal surgery, it is easy to leave a swab undetected within the peritoneal cavity. It is therefore essential to check the number of swabs and instruments, and to account for all, before closing the peritoneum. As all swabs used in surgery should have a radiopaque marker, if a swab is unaccounted for at the end of an operation, an abdominal X-ray should be performed to locate the retained swab.

INTRA-ABDOMINAL OPERATIVE ASSESSMENT

When the peritoneal cavity is entered there is an opportunity not only to assess the pathology for which the operation is intended, but also to check for any other, as yet undiagnosed, condition. For example, peritoneal malignant deposits, although easily visualised or palpated at surgery, are often undetected, even by sophisticated preoperative imaging. Even with a limited-access abdominal incision for the removal of an appendix, it is usually possible to check at least the terminal ileum and the right ovary, which is particularly important if the appendix has proved to be normal. A major abdominal incision allows a fuller assessment, as does a laparoscopy. It is a good discipline to do this immediately on opening the abdomen or it may be forgotten later. Mobilisation of organs, or entry into the lesser sac, is required only if there is a specific concern that justifies these manoeuvres. At open surgery, the small bowel can be followed throughout its length, the omentum elevated and the large bowel palpated as far as the mid rectum. Views may be restricted, but the pelvic organs, stomach, liver and gallbladder can also all be palpated, as can the retroperitoneal organs. At laparoscopy, although visualisation is usually superior, direct palpation is impossible, although instruments allow limited palpation by experienced surgeons.

GASTROSTOMIES, ENTEROSTOMIES AND COLOSTOMIES

The terms gastrotomy, enterotomy or colotomy indicate an incision into the lumen of the gastrointestinal tract. These incisions are closed with a similar technique to a sutured anastomosis, which is described later in this chapter in 'Anastomotic technique'. Gastrostomy, enterostomy and colostomy indicate the establishment of a connection from the lumen of the gastrointestinal tract to the abdominal wall skin. Those in which a mucocutaneous anastomosis, or stoma, is formed, are described in Chapter 14. A connection can also be established by a tube secured into the lumen.

TUBE GASTROSTOMY

A tube gastrostomy may be fashioned when the abdomen is already open. A balloon catheter is introduced through the anterior abdominal wall in a position where the stomach can be apposed to the abdominal wall without tension. A small incision is then made in the anterior stomach wall at the centre of a purse-string suture, the catheter is introduced and the suture tied snuggly around the catheter. The anterior wall of the stomach should then be fixed to the anterior abdominal wall to prevent dragging on the tube, to eliminate a length of intraperitoneal catheter around which the bowel could twist, and to minimise the consequences of any minor leakage. Currently, the most common gastrostomy insertion is performed by a non-operative percutaneous endoscopic gastrostomy (PEG) method.

FINE-BORE TUBE ENTEROSTOMY

Fine-bore tube enterostomy can be used for enteral feeding; the technique for this is described in Chapter 3.

TUBE CAECOSTOMY

Tube caecostomy is established by a similar technique to that used for an open gastroscopy. Its place is limited, but tube caecostomy is generally not advised.

ANASTOMOTIC TECHNIQUE

The basic principles of this procedure are similar whether the surgery is to close a simple incision into the gastrointestinal lumen or to create an anastomosis. A simple opening into a lumen may be made to retrieve a gallstone from the common bile duct or a foreign body from the stomach that cannot be retrieved endoscopically. The duodenum may have been opened to gain access to the ampulla or to oversew a bleeding ulcer. An incision may have been made accidentally into the small bowel during the dissection of adhesions. A clean incision is simply sutured, as in the construction of an anastomosis. However, care must be taken not to narrow a small-diameter lumen, and it is therefore sometimes appropriate to close a short longitudinal incision transversely, provided that this does not put tension on the closure. More often, a lumen is opened prior to a resection or bypass, and the anastomosis is then performed to restore gastrointestinal continuity.

An anastomosis may be either end-to-end (see Figure 7.7), end-to-side or side-to-side (see Figure 7.11). It may be created between two segments of bowel or between the small bowel and another viscus, such as the stomach, pancreas or bile duct. The anastomosis may even be between an isolated loop of small bowel and the bladder. Individual circumstances and techniques are described in the relevant sections, but the principles are universal, whether the anastomosis is hand sutured or stapled and whether it is performed at laparotomy or laparoscopy. In laparoscopic resections, bowel ends can, on occasion, be conveniently brought outside the body, for example when a right hemicolectomy specimen is delivered through a small incision. The anastomosis can then be performed extracorporeally. When an anastomosis must be performed within the abdomen, hand-sewn methods are generally avoided, as suture manipulation is both time consuming and technically demanding, and mechanical stapling devices are used routinely.

BLOOD SUPPLY

For sound healing, a good blood supply to both sides of an anastomosis is crucial. It may be possible to see the vessels in the mesentery or, in an obese patient, to palpate for arterial pulsation in order to choose a site for resection where the blood supply of the divided bowel will be optimal. The viability of the ends must be confirmed before commencing the anastomosis. The mucosa should be pink and the bleeding from cut submucosal vessels should be bright red. (This sign is lost if the bowel is divided by diathermy.) If an artery close to the bowel wall at the level of the anastomosis is divided before ligation, pulsatile arterial bleeding from the cut end is an extra reassurance. A newer technique is to use fluorescence angiography with indocyanine green (ICG) to confirm a good blood supply to the bowel ends prior to anastomosis. This involves administration of ICG intravenously by the anaesthetist followed by the use of a specialised camera to visualise the bowel ends. ICG assessment is not always available, in which case the above measures should be relied upon. When ICG is available, it may be used as an adjunct to provide additional reassurance and may be helpful in cases when there is some uncertainty about the vascularity. In general, the blood supply to the colon is more precarious than that of the small bowel and stomach. A dusky grey-pink mucosa and dark ooze bleeding of venous back-bleeding are indications that the circulation is inadequate for an anastomosis. The ends must then be resected back to healthy, well-perfused tissue. In a side-to-side anastomotic bypass, blood supply is unlikely to be of concern.

TENSION

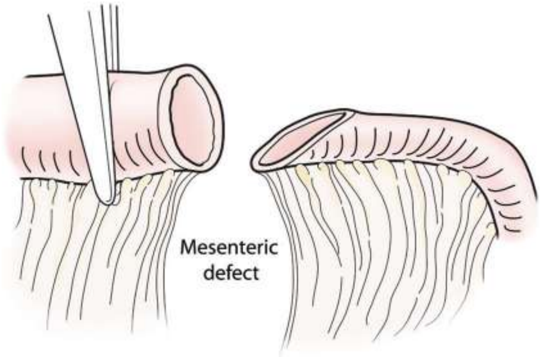
The two sides of the anastomosis must lie easily together without tension, as tension increases the danger of disruption. The surgeon must take into account the likely postoperative increase in tension secondary to inflammatory swelling and ileus. Changes in body position and the filling of the stomach or bladder will also change the alignment and the tension of an anastomosis to these organs. When there is concern, further mobilisation of the ends, without causing damage to the blood supply, is required. If this cannot be achieved, a more sophisticated method of restoring continuity is required.

ANASTOMOTIC DIAMETER

An end-to-end anastomosis inevitably reduces the lumen at the site of the anastomosis, whether hand sutured or stapled. Temporarily, the lumen is further narrowed by postoperative oedema and, if it becomes obstructed, the risk of anastomotic breakdown is increased. This problem is greater if the lumen is of small diameter or the luminal contents are viscous. The traditional sutured two-layer anastomotic technique – which is now seldom used for intestinal end-to-end anastomoses – narrowed an anastomosis significantly as the suture line was invaginated (see Figure 7.8). Paediatric surgeons changed to a single-layer technique before general surgeons, as the narrowing was more critical in the smaller lumen of the neonatal bowel. A side-to-side anastomosis can be fashioned with whatever anastomotic diameter the surgeon chooses. A hand-sewn, end-to-end anastomosis may be enlarged by an oblique division of the ends, or an enlargement can be created by cutting back on the antimesenteric border. This is also a useful manoeuvre if the diameters of the two ends are significantly disparate (Figure 7.6). Temporary stenting of an anastomosis may be protective and is sometimes used for the biliary tract, the pancreatic ducts or the ureter.

MESENTERY

On completion of an anastomosis, there is usually a mesenteric defect, which is a potential site for an 'internal hernia'. The small bowel may pass through this defect, with resultant volvulus or strangulation,



7.6 The anastomotic diameter can be increased by oblique division of the bowel. The mesenteric border should be longer than the antimesenteric border to ensure good blood supply. A longitudinal incision or 'cut-back' at the antimesenteric border produces the same effect. A soft occlusion clamp has been used to prevent the spillage of intestinal contents. After completion of the anastomosis, the mesenteric defect should be closed. ⏎

and most surgeons believe that these defects should be closed (see Figure 7.6). The suture material and method of closure are not important, but care must be taken to avoid injury to mesenteric vessels. A stitch that only picks up the peritoneum of the mesentery is safest.

DRAINS

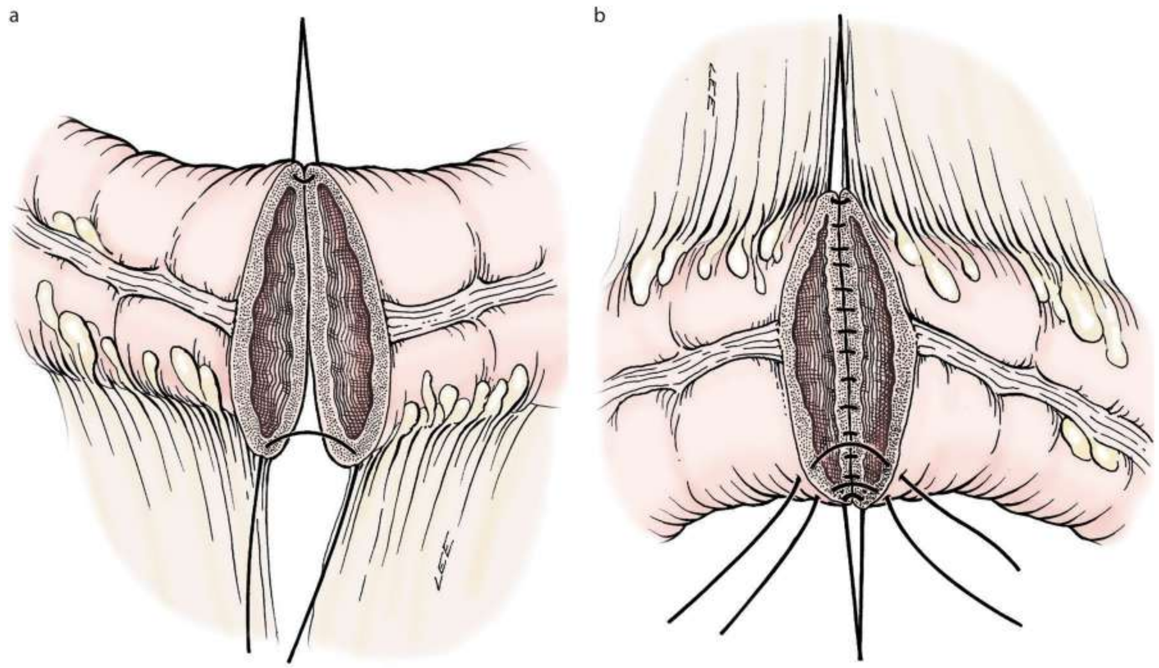
A surgeon may be concerned about an anastomosis because of a marginally adequate blood supply or a degree of tension. There may have been peritonitis at the time of surgery or the patient's general condition may be poor. The surgeon may then consider 'protecting' the vulnerable anastomosis with a drain. However, sutures or staples can hold non-viable tissue in position and delay presentation of a leak for 1–2 weeks. The drain would have to remain *in situ* for 2 weeks to be of any value in this situation, and there is some concern that a drain in contact with an anastomosis for this length of time could in itself cause damage. However, pancreatic anastomoses are particularly prone to delayed leaks and, therefore, pancreatic anastomoses are commonly drained with the drain left *in situ* until this period of danger is passed.

There are, however, some instances in which a short-term drain may be of value. For example, many sound urological anastomoses leak a considerable volume of urine during the first 72 hours but then seal and heal satisfactorily and, in biliary surgery, a significant bile leak may be identified early if a drain is *in situ*. An infected haematoma that has collected in the 'dead space' of the emptied pelvis after a low anterior resection is believed to be one of the causes of anastomotic breakdown when the collection later discharges through the anastomosis. A short-term pelvic suction drain is therefore often employed to prevent this collection and to protect the anastomosis.

Low-pressure suction is preferable to high-pressure suction, which may draw tissue into the drain and cause damage. In addition, low-pressure suction is often more effective, as the drain holes are less likely to be occluded by tissue drawn into them.

SUTURED END-TO-END ANASTOMOSIS

Figure 7.7 illustrates this versatile anastomosis for the colon. However, a sutured end-to-end small bowel anastomosis is often the first that a trainee surgeon performs. Mobility of the small bowel makes the surgery technically easy, the blood supply is good and breakdown is uncommon. As discussed already, the two ends must have a good blood supply and be able to be brought together easily without tension. Discrepancies in diameter between the ends can be adjusted by the spacing of sutures, as the bowel wall is elastic. Alternatively, the smaller lumened tube can be cut at the antimesenteric border to equalise



7.7 An end-to-end bowel anastomosis with a single layer of interrupted extramucosal sutures. (a) The first two sutures are placed at the mesenteric and antimesenteric borders and used as stay sutures. (b) Half of the anastomosis is completed and the bowel has been turned over to suture the second half.

the diameter (see Figure 7.6). Care should be taken with the orientation because, if there is ample mobility, then one end can be inadvertently rotated. The anastomosis should be undertaken without excessive spillage of contents during the procedure, and non-crushing occlusion clamps may be necessary. They are placed proximally and distally to isolate the area of bowel to be opened from the ongoing inflow of gastrointestinal contents until the anastomosis is complete (see Figure 7.6). However, this has the disadvantage of compromising the blood supply, which may be critical to the healing of the anastomosis. Alternatively, a sucker with a guard can be introduced into the divided bowel ends and guided up the lumen to clear contents.

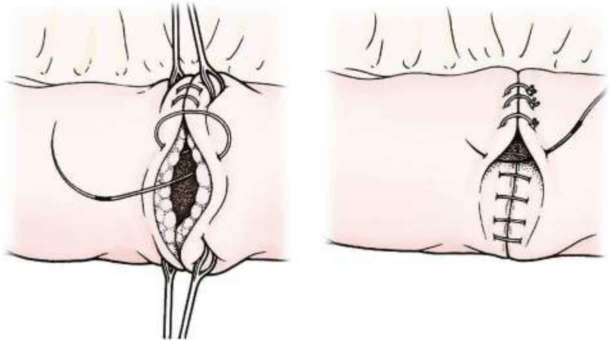
Minor bleeding points in the submucosa can be ignored. Precise coagulation diathermy will stop the more troublesome bleeding points, but many surgeons prefer to divide the bowel with diathermy to reduce bleeding.

Suture material

The choice of suture material is often dependent on the preference of the surgeon; for example, knots may feel more secure with a braided material, but a slippery monofilament material slides better if a parachuting technique is needed. Additionally, the choice between an absorbable and a non-absorbable suture is again often one of personal preference. However, non-absorbable sutures should be avoided in biliary and urinary anastomoses, where sutures, in particular braided material such as silk, have been found as the nidus within a subsequent calculus.

Technique

A single layer of interrupted extramucosal sutures is now favoured by the majority of surgeons. A continuous suture acts like a drawstring and will tend to narrow the lumen, especially in the early phase when postoperative swelling further tightens the suture. In addition, a continuous suture reduces the blood supply to the cut ends; this is disadvantageous except in very vascular areas where a haemostatic suture may be beneficial. Sutures that include the mucosa have no advantage other than haemostasis. They do not add significantly to the strength of the anastomosis, nor do they improve apposition, as the mucosa already lies in apposition after accurately placed extramucosal sutures. The mucosa heals rapidly, and a watertight seal will have formed within 24 hours. Sutures that include the mucosa merely delay this by the trauma and ischaemia that the sutures cause and, in experimental models, a small mucosal ulcer can be seen at each suture site.



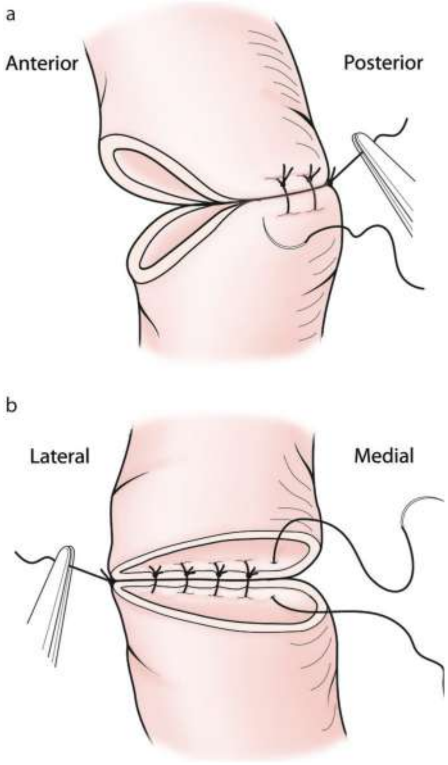
7.8 The classic two-layer anastomosis is now seldom employed for an end-to-end anastomosis. ⏎

Historically, when two layers of sutures were used routinely, it was believed that the second seromuscular layer was important to invaginate and bury the mucosa of the cut ends (Figure 7.8). This does not confer any benefit and causes narrowing and greater tissue strangulation.

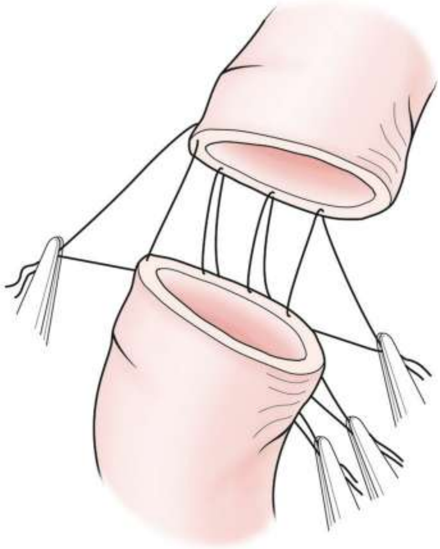
The first two sutures are placed to unite the two ends at the mesenteric and antimesenteric borders, and they divide the anastomosis into two equal sections. These sutures are tied and the ends are left long and held in artery forceps (see Figure 7.7a). Each suture should start on the outside and emerge between the mucosa and the muscularis mucosa. It is important to include the muscularis mucosa, which is visible as a white line, as it has significant strength. These layers are distinct, and mobile on each other, if the bowel has been cut with scissors or a scalpel. Diathermy division of the bowel to some extent 'fuses' the layers, and the anatomy of the layers may be less distinct. The ideal size of the suture bite may be difficult to judge. A larger bite has less danger of cutting out, but it creates a larger bulk of potentially strangulated tissue to narrow the lumen. In the adult small bowel, a reasonable compromise is to introduce the suture 0.5 cm from the cut end. The suture is then introduced into the other cut bowel end between the muscularis mucosa and the mucosa and brought out through the peritoneal surface 0.5 cm from the cut end. Care must be taken as the throws on the knot are tightened to prevent the whole suture tightening and strangulating the tissue. The spacing of sutures is difficult to judge, and the temptation to place them very close, in anticipation of the dilatation of postoperative ileus, should be resisted. The additional compromise to the blood supply outweighs any benefits of an apparently more watertight early closure. In an adult small bowel, sutures at intervals of 0.5 cm are a satisfactory compromise. Subsequent sutures are placed until half of the anastomosis is complete. The bowel is then turned over and the other half of the anastomosis completed (see Figure 7.7b).

In most other situations, access is less ideal, and it is important to first complete the back wall of the anastomosis. A similar technique to that described above can be employed if the surgeon starts at the back corner, which is furthest away, and this first suture is left long as a stay suture. This suture makes the placement of the next suture easier, and it is possible to continue along the back wall of the anastomosis until the back corner nearest the surgeon is reached. This last suture is also left long as a stay suture (Figure 7.9a). The front wall is then anastomosed. Another alternative is to introduce the sutures along the back wall of the anastomosis, from within the bowel lumen (Figure 7.9b). These sutures have knots in the submucosal plane, which in theory is less than ideal but in practice is satisfactory. In a difficult anastomosis when access is very restricted, sutures may be *parachuted* or *railroaded* into position. The two ends are only apposed after all sutures are in place (Figure 7.10). Many of these problems, which are encountered particularly in oesophageal and rectal anastomoses, can be overcome through the use of a circular stapling device.

In some structures, such as the common bile duct, a separate mobile mucosa may not be apparent. The interrupted sutures should then be placed full thickness if it is not practical to exclude the mucosa.



7.9 (a) The back wall of a colorectal anastomosis sutured from behind. All knots are on the serosal surface. (b) An alternative is to place the back wall sutures from within the lumen. The knots will lie in the submucosal plane. ⏎



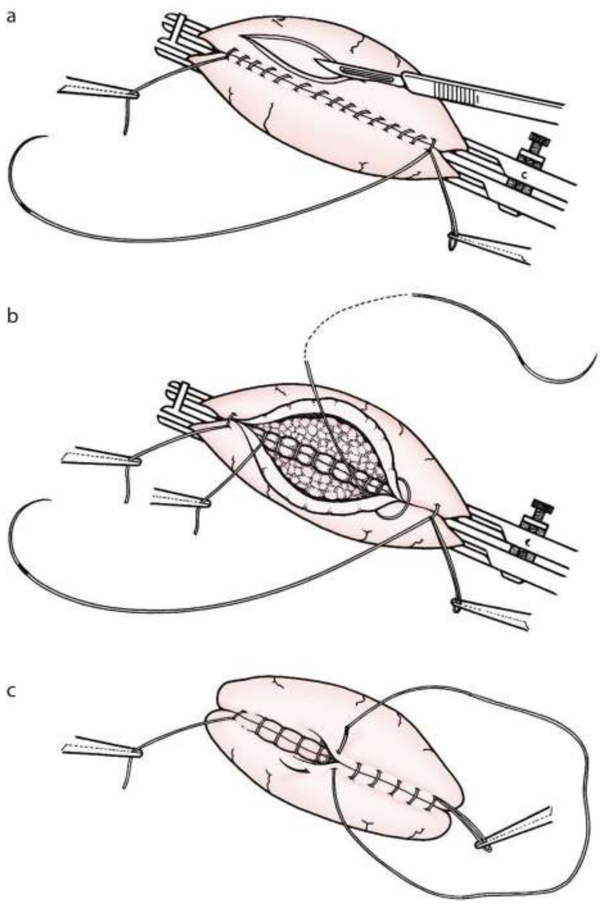
7.10 The sutures are all in place before the two ends are apposed. This 'railroad' technique is useful when access is very restricted. ⏎

An *end-to-side sutured anastomosis* is merely an adaptation of the end-to-end technique. An incision is made in the side of the viscus to which the end is to be joined. The length of the incision should be such that there are two equal 'lumens' for the anastomosis. The suture technique used is similar to that described for an end-to-end anastomosis.

SUTURED SIDE-TO-SIDE ANASTOMOSIS

This is a useful anastomosis when a segment of gastrointestinal tract is to be left *in situ* but bypassed. It may be undertaken in a similar fashion to the end-to-side anastomosis described above and constructed with a single layer of interrupted sutures. However, if both sides of the anastomosis have a rich blood supply, haemostasis of the cut ends is important and a continuous suture technique has advantages. A second suture layer also adds stability to the anastomosis and there is no concern in a wide side-to-side anastomosis that a two-layer continuous technique will significantly narrow the anastomotic diameter. Side-to-side anastomosis is a method commonly employed in anastomoses between the stomach and small bowel. The traditional, hand-sewn technique for gastroenterostomy or enteroenterostomy is described in the following.

Most surgeons use clamps for this operation in order to steady the gut and prevent the escape of contents, but others prefer to rely on a skilled assistant. The clamps must be of the light *occlusion* type (often referred to as 'soft bowel clamps'), which will cause minimal trauma to the segment of each viscus



7.11 A side-to-side anastomosis utilising twin occlusion clamps. (a) The posterior seromuscular suture is completed and the lumen is opened. (b) The posterior all-layer suture is completed and the anterior all-layer suture is in progress. (c) The final anterior seromuscular suture is nearing completion. ⏎

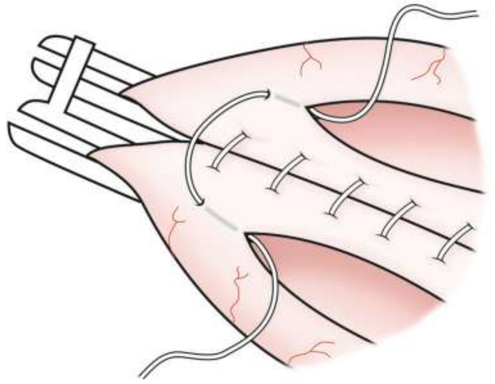
included in the clamp. An 8 or 9 cm portion should be held within the clamp for a gastroenterostomy, but for an enteroenterostomy about half of this length will suffice. A swab is laid underneath to absorb any spillage and the two clamps are approximated. They are secured with a locking device or are tied together (Figure 7.11). The outer suture is a continuous seromuscular suture and the inner suture is an 'all-layer' continuous suture. This is achieved by four separate suturing manoeuvres, as follows.

Posterior seromuscular suture

This is a continuous absorbable suture that does not include the mucosa and that unites the adjacent surfaces of the gut. A short end is retained in forceps at the start of this layer and, at completion, the suture is retained for later use as the anterior seromuscular suture. The suture is tied to the loop of the last stitch at the end of the posterior seromuscular layer. This locks the continuous suture and also provides a loop of suture material that can be held in artery forceps as a stay suture to steady the anastomosis when the clamps are removed. The lumen of each segment is now opened, within the limits of the posterior seromuscular suture, by an incision parallel to the suture line and approximately 5 mm from the suture line (see Figure 7.11a). The incision for a gastroenterostomy will therefore be about 5–6 cm in length. In the first instance, the incision should be made through the serosal and muscular coats only; the mucosa is then picked up with forceps and incised separately. If diathermy is used for the incision, care must be taken to avoid injury to the opposite mucosal layer. On occasions when no clamps are employed, a sucker should be introduced through the initial mucosal incision to remove contents and reduce spillage.

Posterior all-layer suture

This suture begins at one extremity of the incisions and unites the posterior cut edges, traversing all coats of the gut. The first stitch should enter the lumen lateral to the end of one incision and, after ligation, the end of the suture is held in forceps (Figure 7.12). An ordinary over-and-over continuous suture is employed but, after every five or six stitches, a lock stitch may be inserted to prevent a possible purse-string effect as the suture is tightened. When the other extremity of the incisions is reached, the suture is carried round the corner and continued in the reverse direction as the anterior all-layer suture. Particular care must be taken when turning the corner to ensure that an all-layer suture is again placed beyond the extremity of the incision.



7.12 The first suture should enter the lumen lateral to the end of the enterotomy incision. At the other end, care must again be taken to place the suture beyond the extremity of the incision. ⏎

Anterior all-layer suture

This suture begins as a continuation of the posterior layer, with the needle passing from one lumen to the other as before, except that the wall of each gut edge must be traversed separately (see Figure 7.11b). As the suture is tightened, the mucosa is inverted by the loop of thread that has been inserted. Any tendency to eversion can be overcome by the assistant gently pressing on the cut edges with forceps as the suture is tightened. The suture is continued in this manner to complete the join of the cut edges of the gut. The suture is tied to the original end that was held in forceps at the start of the posterior all-layer suture. The anastomosis should now be watertight and the clamps are removed.

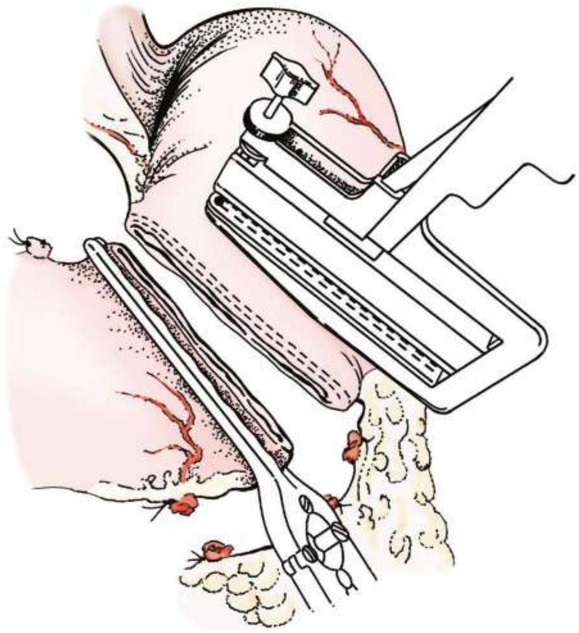
Anterior seromuscular suture

This suture begins as a continuation of the posterior seromuscular suture and on completion is tied to the end that was held in forceps at the start of the procedure (see Figure 7.11c).

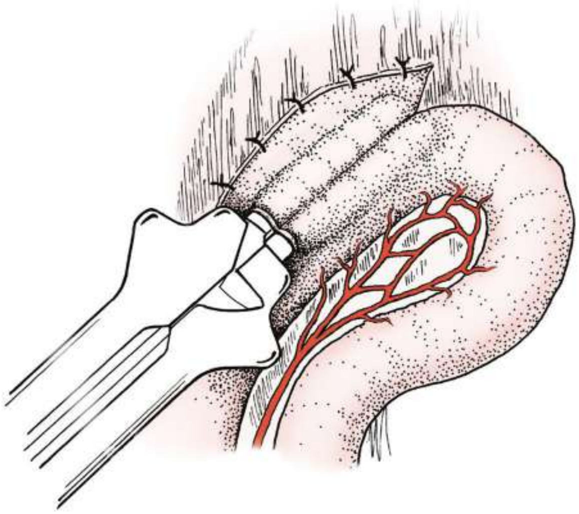
Numerous minor modifications of the traditional, hand-sewn technique for gastroenterostomy or enteroenterostomy are in common use.

MECHANICAL STAPLING DEVICES WITHIN THE ABDOMEN

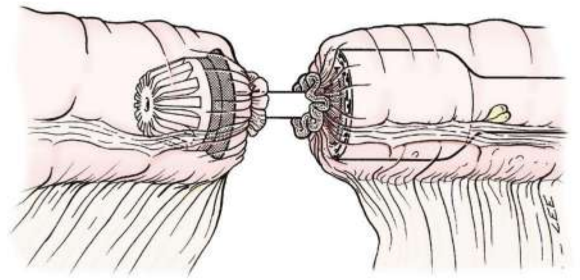
Mechanical stapling devices have progressively replaced the traditional sutured techniques. In many situations in open surgery, the main advantage is speed, while the disadvantage is cost. However, a hand-sewn anastomosis can be very difficult when access is severely limited, and it is in these circumstances that mechanical stapling devices have major advantages. One or more rows, or circles, of staples hold the tissue in apposition. When the device is employed from outside the bowel lumen, the mucosa is held in apposition and an eversion closure of the bowel wall is produced (Figure 7.13). When the device is employed from within the lumen, the serosa is held in apposition with an inversion anastomosis (Figures 7.14 and 7.15). Initial theoretical concerns that healing would be poor when either intact mucosa or intact serosa was apposed have proved to be unfounded. An additional theoretical objection to an everted stapled anastomosis is that it leaves mucosa exposed to the peritoneal cavity. This was against all the early surgical principles of anastomotic technique. In general, little difference has been found in numerous studies comparing outcomes in stapled versus hand-sewn anastomoses. Stapling devices can be divided broadly into linear and circular instruments and into those that incorporate a cutting action and those that do not.



7.13 A crushing clamp temporarily seals the distal stomach, which will be removed in this partial gastrectomy. The proximal stomach has been sealed with a double row of staples delivered from a linear stapling device. The stomach has been divided between the two sealed lines. ⏎



7.14 A linear cutting stapling device, with one blade in the stomach and one in the jejunum, can be used to create a stapled gastroenterostomy. The two small incisions for the insertion of the blades must then be closed. ⏎



7.15 An anastomosis with a circular stapling device. The head and anvil of the device are inserted separately into the two segments of bowel to be anastomosed. The two parts of the device are then locked together and the bowel is approximated over the area through which the staples are to be fired. When the staples are fired, a circular blade amputates the tissue lying within the lumen and this consists of a 'doughnut' of proximal and of distal bowel. ⏎

LINEAR STAPLERS

Linear staplers deliver several rows of parallel staples and may, in addition, have a cutting mechanism between the rows of staples. The staple line is commonly either in line with or at right angles to the handle of the instrument, but other angulations are also available. The preference for each type is dependent on the challenges of access (see Figures 7.13 and 7.14).

Linear staplers without a cutting blade

When fired from outside the bowel, two parallel rows of staples appose the mucosa and close the lumen, but the tissue is not divided (see Figure 7.13). These staplers can be used, for example, to reduce the size of the available stomach in a gastropexy for morbid obesity and to close the rectum below a tumour during an anterior resection. A linear stapler, fired with one blade inserted into an intermittently retracting ileostomy, will hold the serosal surfaces of the spout apposed and may prevent retraction. A simple linear stapler can easily be mistaken for one that also cuts between the staple line, and care must be taken to select the appropriate instrument.

Linear staples with a cutting blade

These extremely useful instruments deliver four to six rows of parallel staples and cut between the middle two staple lines. They may be used for dividing the bowel and sealing both ends.

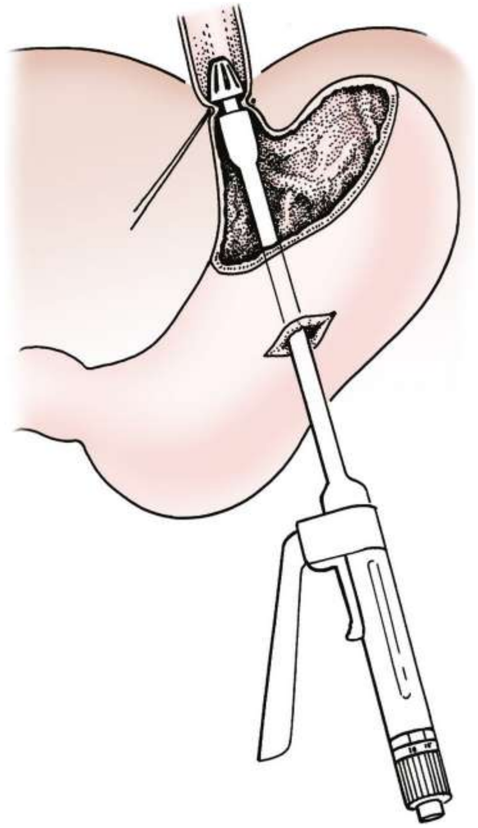
Linear cutting staplers are particularly useful when one end of the bowel is to be brought out as a terminal stoma, as abdominal wall contamination is minimised and the bulk of a clamp is avoided. The distal divided end is also already closed and can be dropped back into the peritoneal cavity. The duodenal division in patients undergoing a gastrectomy is another application of this technique. Many surgeons opt for an additional seromuscular suture both to bury the exposed mucosa and to provide additional security to the closure of a stapled stump left *in situ*. Initially, this was standard practice in many situations to reduce the risk of staple line leaks and haemorrhage, but the necessity for this suture is increasingly questioned.[3] Staple line reinforcement can also be achieved by specifically designed bioabsorbable material, either applied exogenously or incorporated into the staple line. Stapling devices that have this material as an integral feature are advocated by some surgeons.[4]

If the two blades of the stapler are placed in different segments of the gut, firing the device creates an anastomosis (see Figure 7.14). However, there is still the necessity to close the defects through which the blades have been introduced. These stapling devices are used extensively in gastric anastomoses and for creating ileal and colonic pouches. Further details of their use in these situations are described in the relevant sections.

Small linear stapling devices with a cutting blade can secure and divide a blood vessel, and these have a particular role in laparoscopic surgery. Ligation or transfixion ligation is suitable for most vessels that have to be divided at open surgery. Some short, wide vessels cannot be secured in this fashion, and a sutured closure of the short stump of such a vessel is technically demanding if access is restricted. These small linear stapling devices have thus proved extremely useful in this situation and are used, for example, for the division of the hepatic veins in hepatectomy.

CIRCULAR STAPLING DEVICES

Circular staplers are the instruments that have revolutionised the challenges posed by low rectal and oesophageal anastomoses. The instrument can be separated into two portions, which are later locked together. In a classical end-to-end low colorectal anastomosis, the smaller portion (or head) of the instrument is inserted through the cut end of the mobilised descending colon, which is drawn over the instrument with a purse-string suture so that only the locking mechanism protrudes. The main body of the instrument is then introduced through the anus. The distal bowel wall must also be drawn securely over the portion of the device from which the staples are fired. If the rectal stump has been closed by staples, the spike of the shaft of the gun pierces the closed stump. Alternatively, a purse-string suture is inserted into the open end of the distal rectum and drawn around the shaft. It is important that the bites of any purse-string suture are not too large and that any excess tissue has been cleared off the gut that overlaps the ends to ensure satisfactory approximation of the two ends (see Figure 7.15). Staples that are fired through too

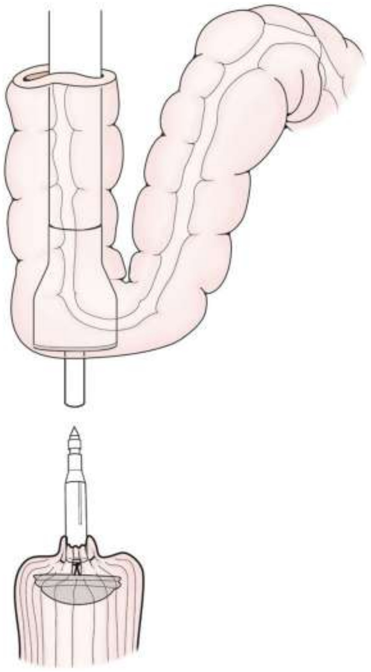


7.16 The circular stapler has been introduced through a separate gastrotomy to perform an oesophageal transection and re-anastomosis for varices. ⏎

great a bulk of tissue will be insecure. A monofilament non-absorbable suture that slides atraumatically through the tissue is most suitable for this purse-string suture. The head of the gun is interlocked with the shaft and the ends are apposed. The device is then ‘fired’. This delivers two circles of staples to form the anastomosis. A circular blade amputates the excess tissue within the staple line as two ‘doughnut’ rings. The stapling device can then be removed. The head has to traverse the anastomosis, and with some instruments the head flips into a vertical plane to ease removal.

There are many possible variations of the above procedure when access to an orifice is not possible or when an end-to-side anastomosis is favoured. The main instrument may be introduced through a separate incision in the lumen (Figure 7.16). Alternatively, the main instrument, or the head, may be introduced through an open cut end (Figure 7.17). The opening for the introduction of the main instrument cannot be closed until after completion of the circular anastomosis, and the surgeon must consider whether access for this closure will still be possible.

A circular stapling device may also be used to transect and re-anastomose an intact segment of the gastrointestinal tract. The instrument is introduced locked but separated so that tissue can be drawn into the gun before the gun is closed. The instrument is fired and a single ‘doughnut’ of tissue excised, and continuity is restored by a circular stapled anastomosis. This technique can be used for oesophageal transection for oesophageal varices. The tissue is invaginated by an external ligature around the oesophagus (see Figure 7.16). A similar principle is utilised in a stapled haemorrhoidectomy, wherein a circumferential suture, confined to the mucosa, is inserted *per anum* and used to draw the mucosa and submucosal haemorrhoidal plexus into a specially adapted circular stapling device (see Chapter 15).



7.17 The circular stapling device has been introduced through the open end of the colon for a side-to-end anastomosis onto the top of the rectum. However, access to the open end of the colon to close it may be difficult. ⏎

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8

Operative management of benign upper gastrointestinal disease

Inian Samarasam, Feroz Khan and Susmitha Barama

ANATOMY OF THE OESOPHAGUS

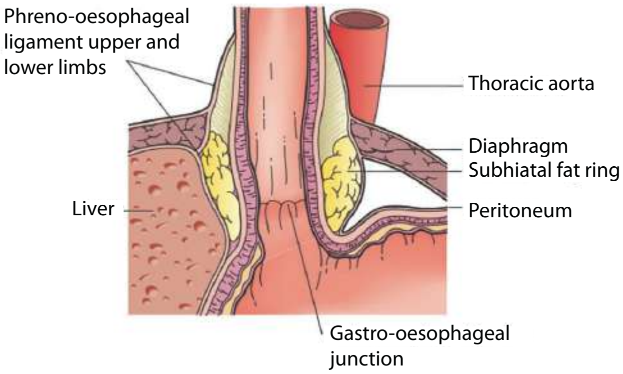
The general anatomy of the oesophagus is outlined in Chapter 9. However, the anatomy of the distal oesophagus is of particular interest to surgeons undertaking benign procedures, particularly those aimed at treating reflux symptoms.

The segment of the oesophagus that lies intra-abdominally is about 3 cm in length. This abdominal oesophagus is more or less retroperitoneal, with peritoneum covering its anterior and left side only. The angle of entry of the oesophagus to the stomach is termed the angle of His and varies from 30° to 70°.

The oesophageal hiatus is formed by the left and the right crura of the diaphragm. The right crus originates from the first three lumbar vertebrae (L1–L3) while the left crus originates from the first two (L1–L2). Tendinous tissue binds the two crura, which meet posteriorly in the midline, along with the median arcuate ligament. This tissue is important, as it is used for placing sutures during crural repair. During hiatal hernia repairs, it is also important to minimise damage to the crural muscle during the hiatal dissection and to take care to keep the epimysium intact.

The phreno-oesophageal membrane, also known as the Laimer or Allison membrane, arises from the subdiaphragmatic fascia and attaches the oesophagus to the diaphragm. It is composed of two limbs: one superior to the diaphragm along 2 to 4 cm of the distal oesophagus and the other extending inferiorly across the cardia and blending into the muscle layer of the stomach (Figure 8.1).

Approximately 3 cm proximal to the oesophageal gastric (OG) junction, the circular fibres increase in thickness and these fibres become short muscular clasps along the lesser curvature. Along the greater curvature and angle of His, the circular fibres become oblique gastric sling fibres. This muscular arrangement extends about 3–4 cm above the OG junction and 1–2 cm onto the stomach forming the high-pressure zone corresponding to the lower oesophageal sphincter on high-resolution manometry (Figure 8.2).


Phreno-oesophageal ligament upper and lower limbs
Thoracic aorta
Diaphragm
Subhiatal fat ring
Liver
Peritoneum
Gastro-oesophageal junction

8.1 Anatomy of the gastro-oesophageal junction: phreno-oesophageal membrane. ⏎

The OG junction is defined by histological, endoscopic and surgical criteria. Histologically, the OG junction is the point where there is an absence of the oesophageal submucosal glands and is the proximal extent of gastric oxyntic glands. Endoscopically, it is the squamo-columnar junction, Z line or proximal extent of the gastric mucosal folds. Surgically, the OG junction is identified by the peritoneal reflection on the stomach and marked by Belsey's pad of fat.

GASTRO-OESOPHAGEAL REFLUX DISEASE

Gastro-oesophageal reflux disease (GORD) is defined as 'a condition caused by the reflux of stomach contents, causing troublesome symptoms and/or complications' (Katzka and Kahrilas, 2020). The symptoms may be 'typical', such as heartburn, regurgitation, water brash, chest pain or dysphagia, or 'atypical', such as asthma, aspiration, cough, globus hystericus or dental erosions.

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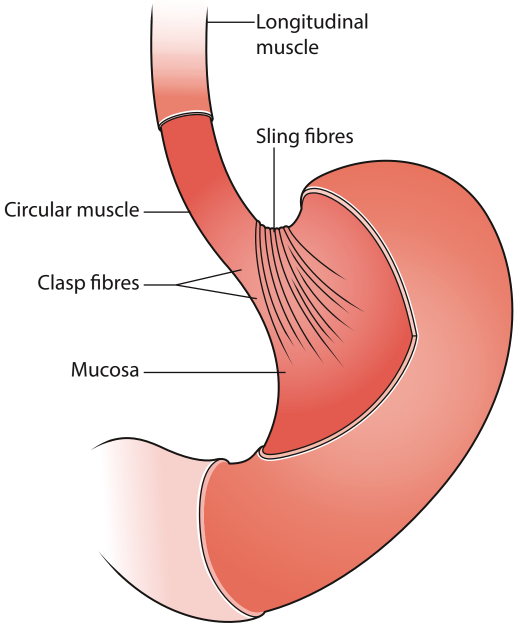


8.2 The clasp fibres and sling fibres at the OG junction. ⏎

Indications for surgical treatment

- Incomplete response to medical management
- Endoscopic findings of significant hiatus hernia or of complications of GORD such as Barrett's oesophagus, reflux oesophagitis or peptic stricture
- Extra-oesophageal manifestations of GORD such as asthma, hoarseness, cough, chest pain or aspiration

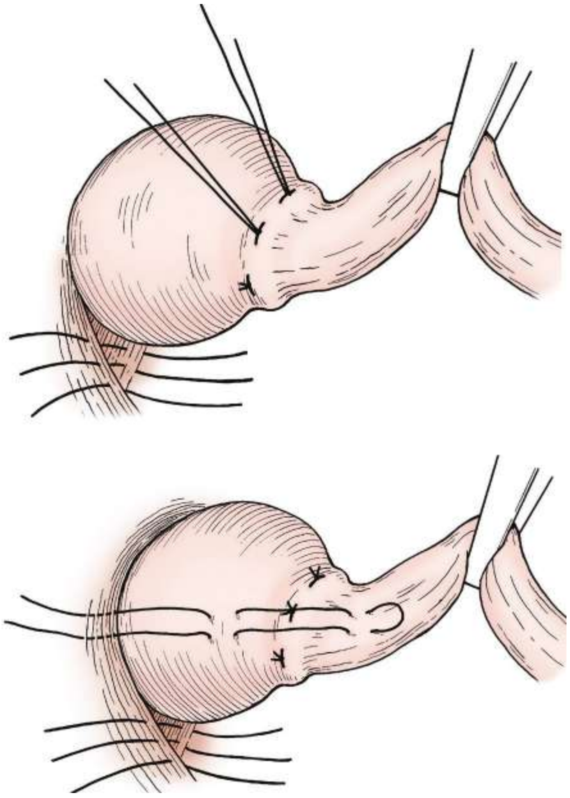
Surgical options

A variety of different operations have been developed over the years for the treatment of GORD. The principles of surgery, irrespective of the technique used, include:

- Mobilisation of the lower oesophagus and maintenance of an adequate length of the intra-abdominal oesophagus
- Reduction of any hiatus hernia
- Crural closure
- Fundal wrap

Belsey Mark IV operation

Before the advent of the laparoscopic era, the Belsey Mark IV procedure was the gold-standard operation. It is a partial anterior wrap, undertaken through a left sixth intercostal space posterolateral thoracotomy. The gastric fundus is plicated to the lower 4 cm of the oesophagus for 270° anteriorly and laterally, while leaving the posterior quarter of the oesophagus and the posterior vagus nerve undisturbed (Figure 8.3). Sutures are placed posteriorly in the crural opening to narrow the hiatus.



8.3 Belsey Mark IV procedure. ⏎

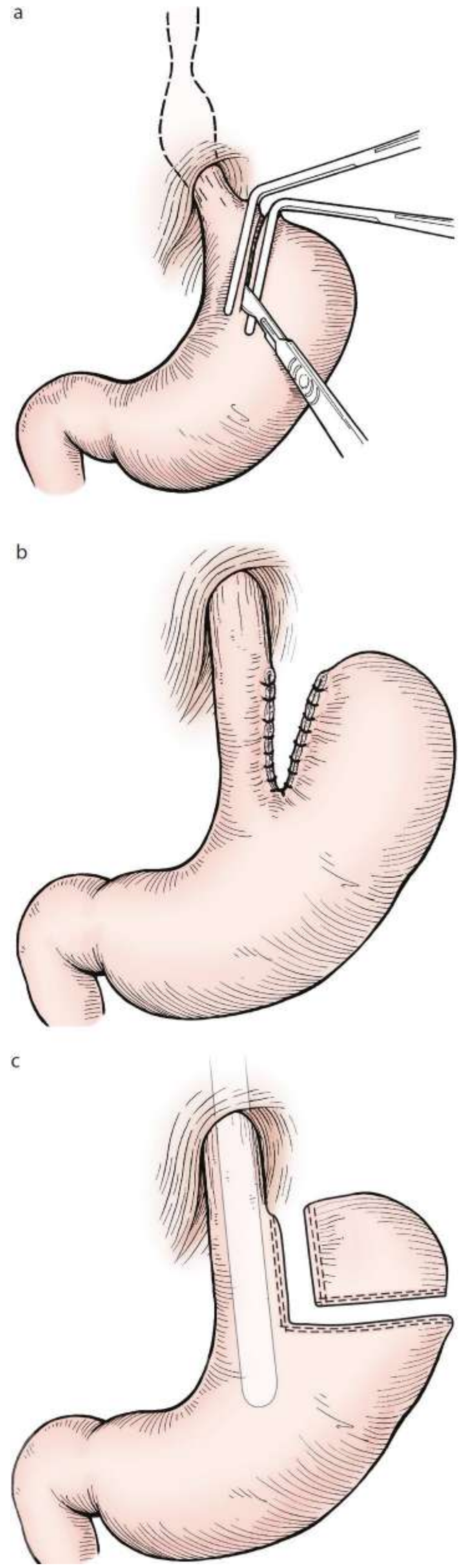
Collis gastroplasty

The Collis procedure is designed to give a tension-free repair for patients with a hiatus hernia in combination with a 'shortened oesophagus'. This procedure involves the creation of a tube of the gastric lesser curvature to recreate the abdominal length of the oesophagus, around which a fundoplication can be performed (Figure 8.4). A disadvantage of this procedure is that the gastric tube does not have peristaltic activity and, furthermore, it can secrete acid. Therefore, this leads to a poor overall success rate.

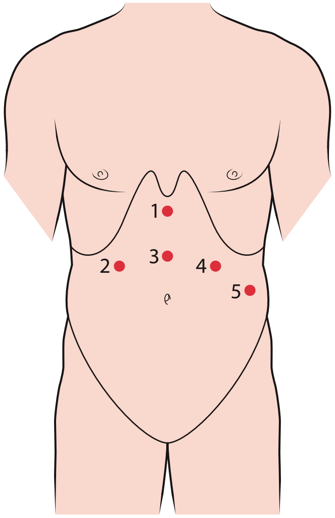
Nissen's fundoplication

The fundoplication, introduced by Rudolf Nissen in 1956, is the most popular anti-reflux operation performed today and is now almost exclusively performed by laparoscopic surgery, although increasingly, where available, robotic platforms can facilitate Nissen's fundoplication.

Patient positioning and equipment After induction of general anaesthesia, a Foley catheter is placed to decompress the urinary bladder and the patient



8.4 Lengthening of the oesophagus by creating a neo-oesophagus in the abdomen. (a) Planning of the vertical suture/staple line, parallel to the left lateral margin of the oesophagus. (b) Vertical suture/staple line executed. (c) Completion of the fundoplication. ⏎



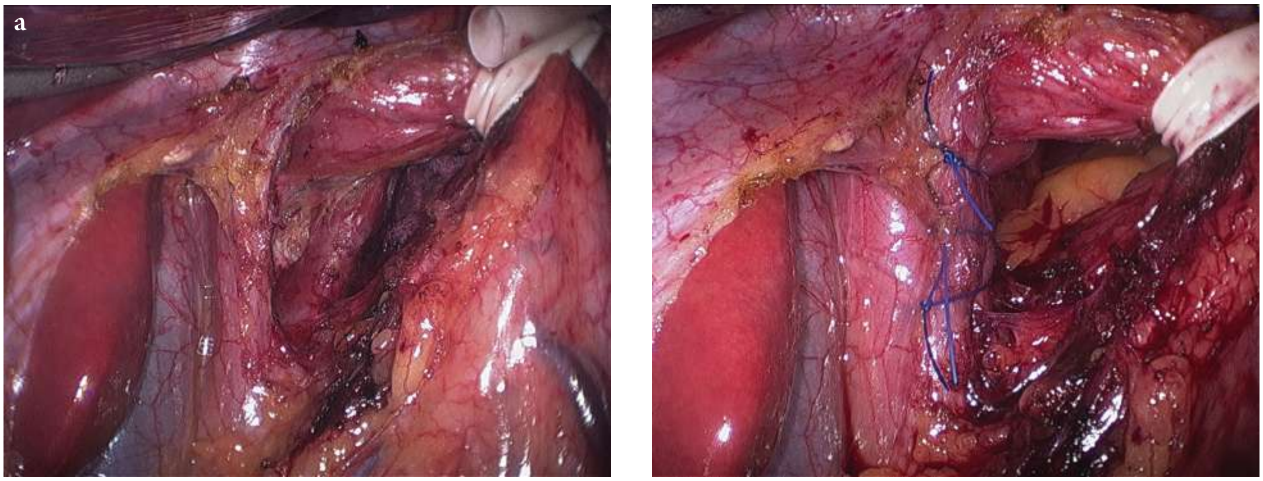
8.5 Port placement for laparoscopic anti-reflux surgery: 1, liver retractor; 2, left-hand working port; 3, camera port; 4, right-hand working port; 5, assistant's grasper. ⏎

is placed in split-leg position. The patient is firmly secured to the operating table (vacuum beanbag mattress) and padded, to obtain a head-up position. The surgeon stands between the patient's abducted legs facing directly forwards. Video monitors are placed at the head of the table. Instruments such as angled laparoscopes (30° or 45°), self-retaining liver retractors (Nathanson's) and atraumatic grasping instruments are essential for this procedure. The port placement is shown in Figure 8.5. It is important to note that the telescope port is placed above the umbilicus for any hiatal surgery, as this offers an optimal view of the hiatus.

Operative details The pars flaccida of the gastrohepatic ligament is opened, taking care to identify and preserve the hepatic branch of the vagus. A replaced left hepatic artery, arising from the left gastric artery, may be present in the area, and this may need to be preserved.

The dissection along the lesser curve is extended up to the OG junction. The right crus is now exposed, and the peritoneum over the right crus is divided. The dissection is continued over the arch of the hiatus, towards the left side. Care should be taken to identify and preserve the anterior vagus nerve. The peritoneum in the angle of His region is then dissected to create a window.

A plane between the oesophagus and the right crus is identified by blunt dissection and an instrument is gently passed behind the oesophagus, from the right to the left side. A sling, or a Penrose drain, is then used to encircle the oesophagus and retract the OG junction. At this point, care should be taken to visualise the posterior vagus and preserve it. The gastric

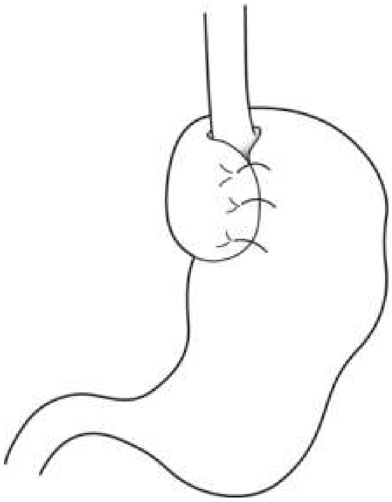


8.6 Intraoperative photographs showing (a) hiatal dissection and (b) crural repair. ⏎

fundus is mobilised by retracting the left lateral border of the fundus to the right and the gastrosplenic ligament to the left. The lesser sac is entered by division of the short gastric vessels.

After adequate oesophageal mobilisation, the crura are re-approximated posterior to the oesophagus by using non-absorbable sutures. The crural repair is fashioned such that the oesophagus is snug, but not too tight (Figure 8.6). A bougie or scope in the lumen of the oesophagus may help in sizing the hiatal closure. It should be possible to pass an instrument between the oesophagus and the crura so that it is not too tight.

Fundoplication The posterior wall of the fundus is grasped and passed from the patient's left to the right side, behind the oesophagus. A 'shoe-shine manoeuvre' is performed to check for adequacy and tension and to also rule out the presence of redundant fundus posterior to the oesophagus. A 56F dilator may be used as a bougie. A complete 360° wrap is then performed to create the fundoplication. The wrap should not be tight and a grasper should be able to slide below the wrap, along the oesophagus, with ease (Figure 8.7).



8.7 Nissen's fundoplication. ⏎

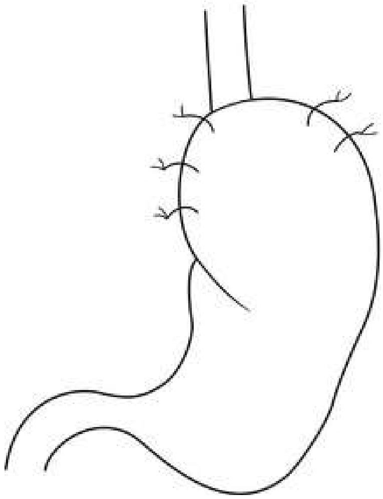
The original Nissen's fundoplication technique involved a wrap of 5 cm in length. The side effects of this procedure included dysphagia, bloating and decreased ability to belch. Therefore, modifications of the original Nissen's procedure included shortening of the fundoplication to 1–2 cm in length and the use of a larger bougie to decrease the incidence of the above-mentioned complications. Another modification is the 'floppy Nissen', involving extensive fundal mobilisation with division of the short gastric vessels.

Anterior partial fundoplication

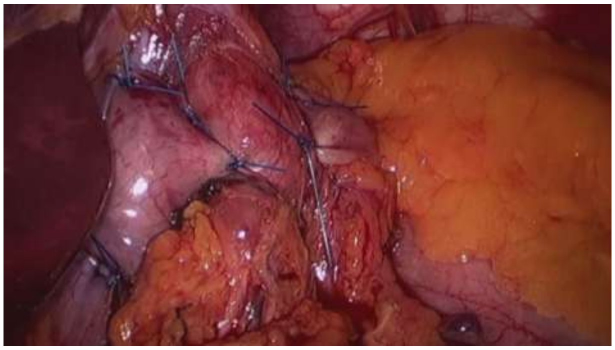
Partial fundoplication techniques are associated with less dysphagia and bloating after surgery. The Dor procedure is a 180° anterior partial fundoplication and has been used primarily along with the laparoscopic Heller's myotomy, as an anti-reflux procedure (Figure 8.8). Similarly, an anterior 120° and 90° partial fundoplication has been described by Watson et al. (1991) and it entails the creation of an anterior wrap by suturing the fundus to the right anterolateral aspect of the oesophagus.

Posterior partial fundoplication (Toupet's)

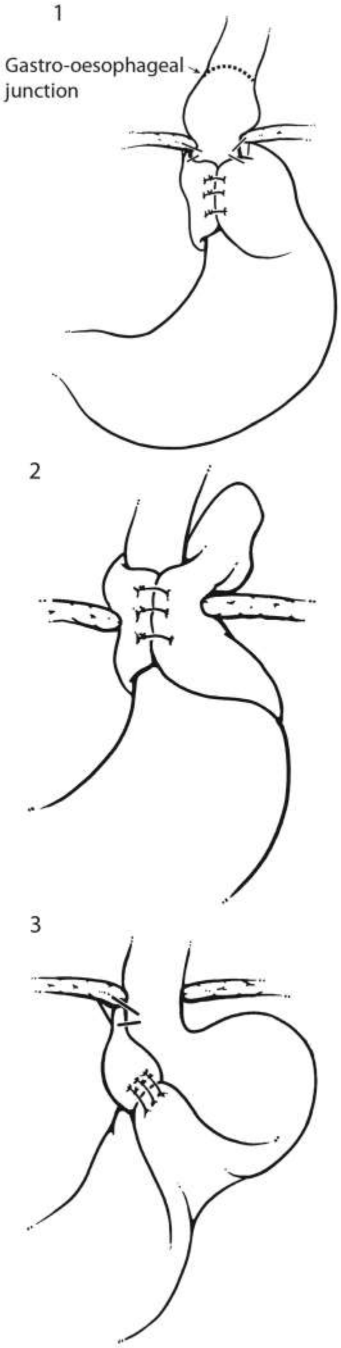
In the Toupet's posterior partial fundoplication, the fundus is passed behind the oesophagus to create a 270° wrap. Sutures are placed to the left and right lateral walls of the oesophagus and to the right crus (Figure 8.9).



8.8 Anterior fundoplication (Dor procedure). ⏎



8.9 Posterior partial (Toupet's) fundoplication. ⏎



8.10 Failure of fundoplication: types 1, 2 and 3. ⏎

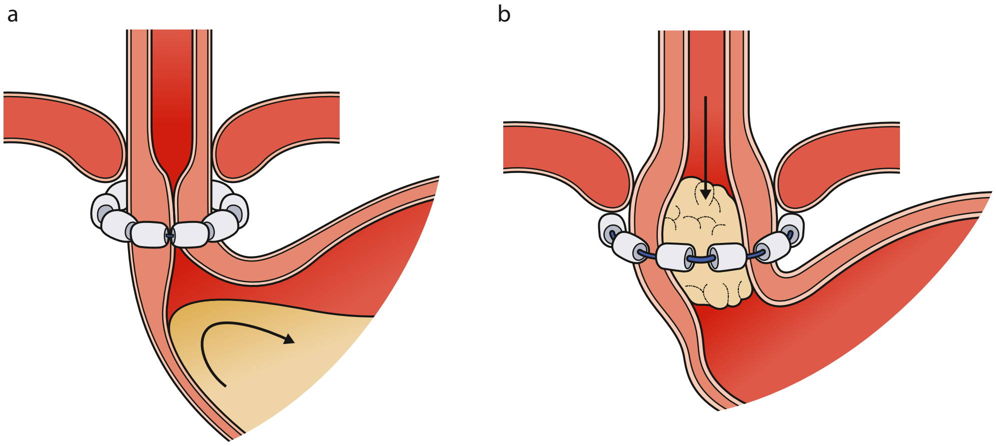
COMPLICATIONS ASSOCIATED WITH LAPAROSCOPIC ANTI-REFLUX SURGERY

- Dysphagia
- Para-oesophageal hiatus hernia
- Bilobed stomach and slipped fundoplication
- Injury to major vessels
- Perforation of upper gastrointestinal tract
- Cardiac tamponade
- Pneumothorax and pneumomediastinum

'FAILED' ANTI-REFLUX SURGERY

Failure after anti-reflux surgery is a difficult problem and the causes of failure need to be looked into in detail, with an appropriate management strategy. In cases of failed surgery, it is crucial to take a proper history, including the exact nature of symptoms, the time frame after which the symptoms appeared, the results of investigations done prior to surgery and specific details of the operative procedure performed. The patient needs to be investigated thoroughly to include an upper gastrointestinal endoscopy, barium study, computed tomography (CT) scan of the abdomen and physiological studies including pH study and manometry.

Once the patient has been fully evaluated, and the cause of failure identified, revisional or redo surgery may be planned. Horgan's classification classifies the recurrences into type 1 (slipped wrap), type 2 (herniated wrap) and type 3 (wrap placed low down in the body) (Figure 8.10). It is important to remember that there may be more than one cause leading to failure.



8.11 LINX system. ⏎

A redo operation will involve the complete take down of the wrap, mobilising the OG junction, hiatal repair and redo wrap.

PROCEDURES INVOLVING AUGMENTATION OF THE LOWER OESOPHAGEAL SPHINCTER

Angelchick prosthesis

This involves the placement of a gel-filled silastic prosthesis in the region of the gastro-oesophageal junction (GOJ). This procedure had an unacceptably high rate of dysphagia, and migration of the prosthesis was a significant problem. Due to the long-term problems associated with this procedure, it is now consigned to surgical history, although there are patients who still have the prosthesis.

LINX technique

The device consists of a series of titanium beads containing a magnetic core. The device is placed laparoscopically around the external oesophagus at the GOJ (Figure 8.11a). When a patient swallows, the peristaltic pressure overcomes the magnetic attraction and the device opens (Figure 8.11b). As the food bolus passes through, the pressure drops and the beads are drawn closed by magnetic attraction (Figure 8.11a). This device is not suitable for patients with GORD complicated by large herniae, Barrett's oesophagus or advanced oesophagitis.

HIATUS HERNIA

Hiatal herniae occur when the stomach, or other intra-abdominal organ, herniates through the diaphragmatic oesophageal opening into the chest. Herniae can be divided into sliding and rolling (para-oesophageal) herniae.

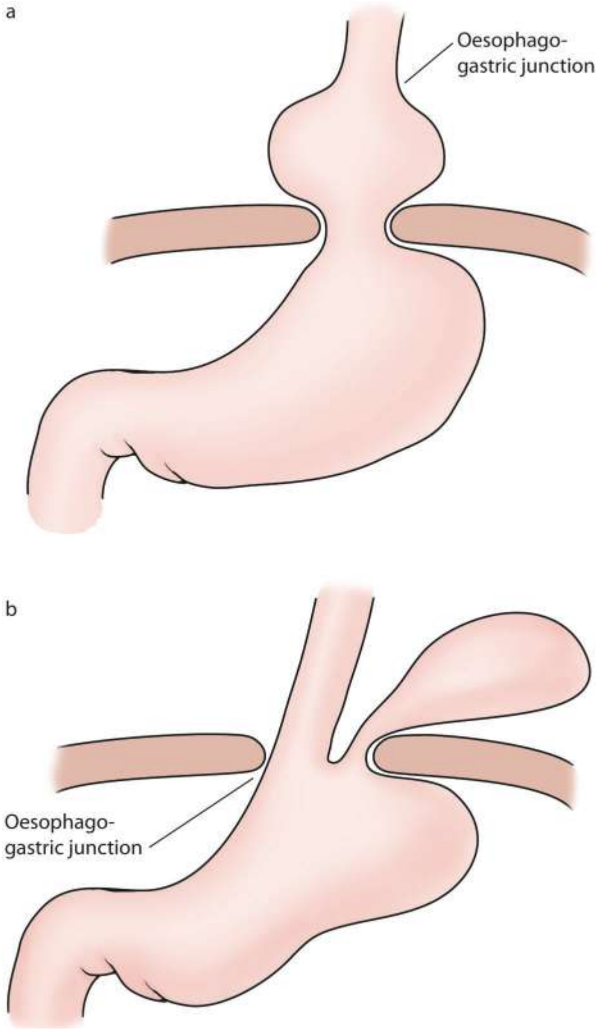
SLIDING HIATAL HERNIA (TYPE 1)

This is the most common type, accounting for over 90% of cases (Figure 8.12a). The cardia and the OG junction undergo cephalad migration through the diaphragm into the posterior mediastinum, but maintain their anatomical relationship. In the initial stages, the oesophageal length is normal and there is no true peritoneal sac. Patients commonly complain of reflux symptoms, which are attributed to functional disruption of the lower oesophageal sphincter. These herniae do not need to be considered for repair unless they are associated with pathological reflux that significantly interferes with the patient's quality of life.

PARA-OESOPHAGEAL (ROLLING) HIATUS HERNIA

Para-oesophageal (rolling) hiatus herniae are subdivided into three types:

1. *Simple rolling hiatus hernia (type II)*. Here, the OG junction remains below the diaphragm, despite the gastric fundus rolling along the oesophagus (Figure 8.12b). The OG junction remains tethered to the diaphragm by an intact phreno-oesophageal ligament and the oesophageal length is maintained. This type of para-oesophageal hernia is found predominantly in older people. Iatrogenic para-oesophageal herniation is seen with increased frequency as a complication following anti-reflux surgery.



8.12 Types of hiatus hernia. (a) Sliding hiatus hernia. (b) Rolling hiatus hernia. ⏎

2. *Mixed para-oesophageal hernia (type III).* This consists of a combination of type I and type II, in which both the fundus and the cardia migrate above the diaphragm.
3. *Large para-oesophageal hernia (type IV).* In this case, the spleen, colon, small bowel, stomach or other intra-abdominal organ herniates into the mediastinum through the hiatal defect. This type carries a significant risk of strangulation.

Most para-oesophageal herniae are asymptomatic and the diagnosis is often a result of an upright chest X-ray that demonstrates an air–fluid level in the chest. However, para-oesophageal herniae may present with gastrointestinal symptoms including dysphagia, regurgitation or chest pain. Bleeding from ulcerated gastric mucosa may result in a haematemesis or an iron-deficiency anaemia.

The evaluation of these patients includes a complete history and physical examination. Standard workup typically consists of a barium swallow, upper endoscopy and oesophageal manometry. CT scans and cross-sectional imaging are particularly valuable in type IV herniae to determine the type of hernia and to show which abdominal organs have migrated into the hernial sac.

SURGICAL MANAGEMENT

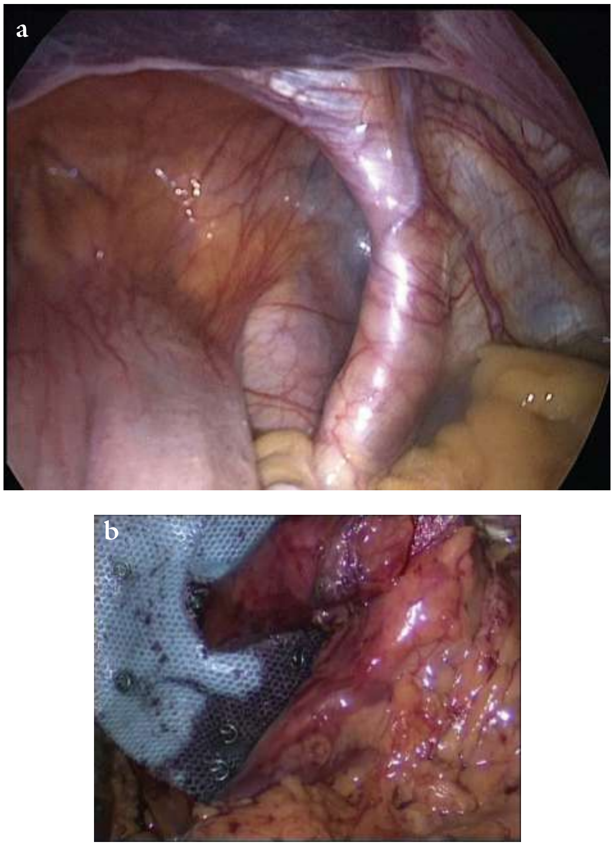
Operative repair is warranted for all symptomatic para-oesophageal herniae and should be considered on all large herniae (even if asymptomatic). The repair generally includes the following steps:

- Complete reduction of the mediastinal sac
- Complete oesophageal mobilisation
- Tension-free hiatal closure

The minimally invasive approach is the preferred technique of repair. The initial preparation, and port placement, are similar to the description for anti-reflux surgery (see Figure 8.5). The stomach and any other herniated contents of the sac are gently reduced. Long-standing adhesions may have to be divided by an energy device and gentle traction during reduction to avoid damage to the contents during the reduction. Both of the crura are defined, as performed in laparoscopic anti-reflux surgery. The most important step is the complete dissection and full reduction of the hiatal hernia sac into the abdominal cavity. This needs to be performed in the correct plane to avoid injury to the mediastinal pleura and vagal nerves. If the sac is not brought down, this will invariably result in recurrence. Once the sac is freed and brought down intra-abdominally, the redundant sac is then excised, taking care to preserve the vagal nerves.

The next step involves closure of the hiatus. The right and left crural fibres are repaired behind the oesophagus, and this is helped by elevation of the oesophagus anteriorly, using an umbilical tape or a Penrose drain for retraction. Care is taken to visualise the posterior vagus nerve, which is included in the sling along with the oesophagus, and elevated. The crura are approximated using 2/0 non-absorbable sutures, starting inferiorly. Very rarely, some sutures have to be inserted anterior to the oesophagus to prevent excessive angulation.

Generally, primary cruroplasty will be feasible in most hiatal herniae, including large para-oesophageal herniae (with defects up to 5 cm). The tips and tricks for primary cruroplasty include maintaining the fascial coverings over both the hiatal pillars, adequate mobilisation of the oesophagus, removal of the sac to accurately identify the OG junction, reducing the insufflation pressure to 8 mmHg while suturing and using relaxing incisions in the diaphragm. Relaxing incisions in the diaphragm may allow for closure of the hiatal defect.



8.13 Intraoperative images of a laparoscopic para-oesophageal hernia repair using a mesh at the hiatus. (a) Laparoscopic view of the para-oesophageal hernia, prior to repair. (b) Para-oesophageal hernia repair with mesh placement at the hiatus. ⏎

The use of any prosthetic mesh at the hiatus has disadvantages, such as stricture, stenosis, late erosion into the oesophagus and increasing difficulty of revision surgery. Therefore, there is *no* role for routine mesh reinforcement of the hiatus. Mesh needs to be used only if primary closure is not possible or is suboptimal. Synthetic meshes are more durable than biological meshes, although they should be used cautiously. It is important to avoid bridging meshes encircling the oesophagus and ensure careful use of mesh tackers during mesh fixation (Figure 8.13).

Generally, an anti-reflux procedure is performed along with the hiatal hernial repair. A partial fundoplication helps prevent the development of reflux and it is a very good form of gastropexy, anchoring the stomach below the diaphragm, thereby helping to reduce recurrence.

ACHALASIA OF THE CARDIA

Greater understanding of the pathophysiology of oesophageal motility disorders has contributed to improvements in diagnosis and treatment. Although a variety of non-specific oesophageal motility disorders are recognised, achalasia cardia is the most important.

Achalasia is characterised by a loss of peristalsis, typically affecting the distal two-thirds of the oesophagus, in conjunction with failure of the lower oesophageal sphincter to relax in response to swallowing. A very similar achalasia can develop secondary to infection with the South American protozoal organism *Trypanosoma cruzi* (Chagas disease).

PRESENTATION AND DIAGNOSIS

Patients complain of progressive dysphagia, retrosternal chest discomfort and regurgitation of food. In many cases, there is a delay in diagnosis, with symptoms being attributed to cardiac or respiratory pathologies. With time, patients may develop proximal oesophageal dilatation with retention of large amounts of food residue. Delays in diagnosis increase the risk of complications such as development of oesophageal diverticula, respiratory symptoms from aspiration and squamous cell carcinoma secondary to chronic inflammation.

All patients in whom achalasia is suspected require evaluation, including a chest X-ray, barium swallow, upper gastrointestinal endoscopy and manometry studies. Endoscopy is an important investigation to exclude 'pseudoachalasia'. This term is used to describe an appearance on barium swallow typical of achalasia despite an underlying pathology such as an oesophageal malignancy or a benign peptic stricture. Manometry is the gold standard in the diagnosis of achalasia. In the typical case, it will identify raised lower oesophageal sphincter pressure (>25 mmHg) with loss of peristalsis in the body of the oesophagus.

Based on the manometry findings, achalasia is classified into three types (Chicago classification, Pandolfino et al. [2008]):

- Type 1 (classic) minimal oesophageal pressurisation
- Type 2 with pan-oesophageal pressurisation
- Type 3 with spasm

This classification helps in deciding the management of achalasia.

MANAGEMENT

- Pharmacological therapy
  - Nitrates and calcium channel blockers
  - Botulinum toxin (endoscopic injection)
- Mechanical destruction of the lower oesophageal sphincter
  - Endoscopic pneumatic dilatation
  - Heller's myotomy
  - Per-oral endoscopic myotomy (POEM)

The mainstay of pharmacological therapy includes long-acting nitrates and calcium channel antagonists. Botulinum toxin injected under direct vision into the lower oesophageal sphincter helps decrease sphincter pressure, providing symptomatic relief.

Pneumatic dilatation is commonly used to disrupt the lower oesophageal sphincter. A balloon is placed across the OG junction under fluoroscopic guidance and inflated to its maximum diameter. Oesophageal perforation is a potential complication and, hence, patients should have a water-soluble contrast study to check for leaks. Approximately 70% of patients obtain symptomatic relief, but they may require a further procedure within 3 to 5 years.

As a myotomy is technically more difficult following pneumatic dilatation and botulinum injection, it is prudent to avoid a dilatation/injection as first-line treatment in younger patients who are suitable for surgery, particularly as surgery has better long-term results. These modalities are currently useful in older patients and those who are high-risk candidates for surgical intervention.

Heller's cardiomyotomy

Surgical myotomy was performed initially by Heller in 1913, which included a thoracotomy with two separate diagonally opposite myotomy incisions. The technique has undergone several modifications, as currently single myotomy with the addition of fundoplication to reduce the incidence of iatrogenic gastric reflux is considered best practice. Traditionally, an extensive myotomy was performed through a posterolateral thoracotomy approach, and this has now been replaced with a myotomy approached via the abdomen. The principle underlying this procedure is to reduce the lower oesophageal sphincter pressure by dividing the muscle wall, while avoiding any breach to the underlying mucosa. The myotomy should include at least 5 cm of oesophageal muscle fibres and 2–3 cm of gastric muscle wall. In total, the ideal length of myotomy should be around 7–8 cm. Patients who present very late, with a significantly dilated and tortuous oesophagus (end-stage achalasia), may require an oesophagectomy. However, even in these patients, a myotomy may be performed as a first step prior to oesophagectomy.

Laparoscopic Heller's myotomy

Patients are positioned in the lithotomy position in the reverse Trendelenburg position, with the operating surgeon standing between the legs and assistant surgeons on either side. Port placement is similar to that for a laparoscopic anti-reflux operation, as described earlier (see Figure 8.5).

The steps of the procedure are as follows.

Division of the pars flaccida (gastrohepatic ligament) The left lobe of the liver is retracted and the GOJ is adequately exposed. The pars flaccida is divided starting above the caudate lobe of the liver towards the right crus. The oesophagus is then separated from the right crus with gentle blunt dissection. At this point, the posterior vagus nerve should be identified and preserved.

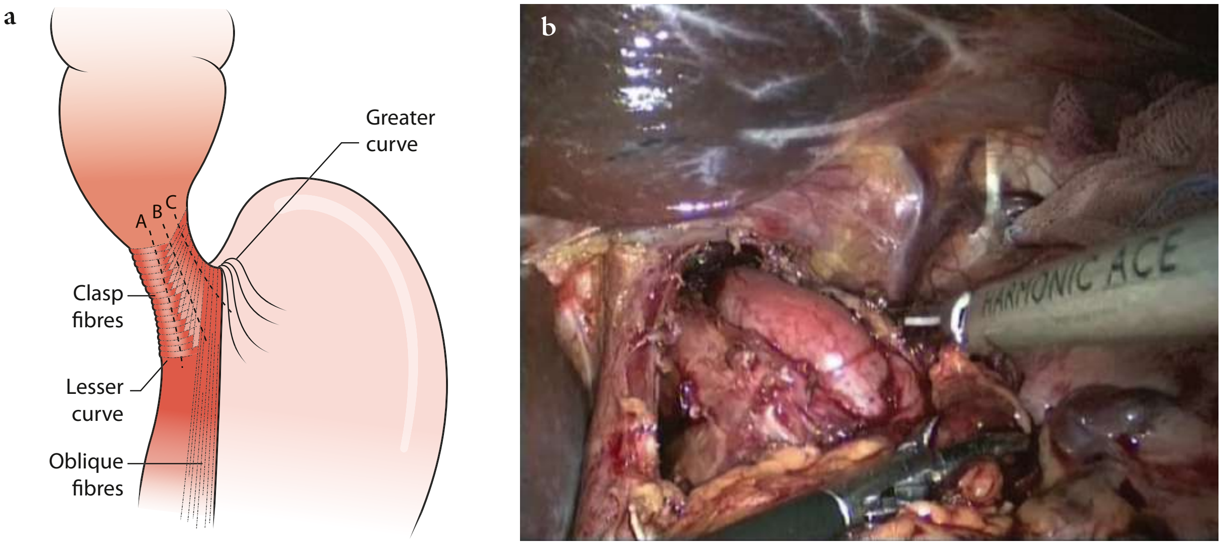
Division of the phreno-oesophageal membrane The phreno-oesophageal membrane is incised and divided clockwise above the oesophagus. The anterior vagus is identified and is left attached to the oesophageal wall. The oesophagus is then gently separated from the left pillar or the crus. When a Dor fundoplication is planned, the dissection is limited to the anterior and lateral aspects of the oesophagus and it is not necessary to perform the posterior dissection of the oesophagus.

Myotomy The gastro-oesophageal (Belsey's) pad of fat is dissected off from the anterior surface of the stomach to expose the GOJ. Once the myotomy surface is exposed, care should be taken to preserve the anterior vagus, which lies close to the oesophageal wall. The myotomy is commenced proximal to the GOJ, as the layers are poorly defined at the GOJ. Using electrocautery, muscle fibres are divided initially. Then, with blunt dissection, the fibres are split until the submucosal plane is seen. Then the myotomy is extended about 5–6 cm proximal to the GOJ on the oesophagus and 2 cm distally on the gastric side, which includes the sling fibres. Bleeding can occur from the muscle edges or the submucosal plexus. The myotomy is placed on the anterior wall of the GOJ in such a manner that the sling fibres are spared (Figure 8.14). Compression with gauze is preferable to electrocautery to avoid injuring the oesophagus. If an oesophageal perforation occurs, it should be repaired using a fine absorbable suture material.

Dor fundoplication A partial fundoplication is performed to decrease the risk of postoperative reflux. The Dor fundoplication is a 180° partial anterior wrap and comprises three stitches that include the fundus and the right pillar of the crus. This also helps to cover, and provides buttressing to, the myotomy on the anterior surface. A posterior Toupet's wrap may also be performed, wherein the edges of the myotomy are sutured on either side of the wrap, which may help to keep the myotomy open. However, a complete Nissen's fundoplication is generally not recommended in order to avoid postoperative dysphagia.

Per-oral endoscopic myotomy

POEM is an established endoscopic treatment modality for achalasia cardia and spastic oesophageal motility



8.14 Laparoscopic Heller's myotomy. (a) Placement of the myotomy on the anterior surface of the OG junction. The myotomy lines A and B are acceptable, whereas C is not done, as this will cause significant damage to the sling fibres. (b) Intraoperative image of a laparoscopic Heller's myotomy. ⏎

disorders. Current guidelines endorse POEM as a primary treatment option for achalasia. While the safety and efficacy of POEM are now well established, the occurrence of postoperative GORD is still a concern. POEM is superior to a laparoscopic Heller's myotomy in the management of type 3 achalasia cardia because of the ability to perform a long intrathoracic myotomy.

POEM involves four main steps that vary in specifics between surgeons and institutions. Endotracheal intubation is typically performed, and the patient is placed in the supine position. The key steps of POEM are as follows:

1. Mucosectomy
2. Creation of a submucosal tunnel
3. Myotomy (in the 5 o'clock position, mainly of the circular muscle layer)
4. Closure of the mucosectomy

Overall, the complication rate after POEM is low; complications in 3.2% of patients were reported by Inoue et al. (2010). Studies employing endoscopic and pH monitoring have revealed a notably high incidence of GORD following POEM. As the incidence of myotomy is related to the length of the myotomy performed, new technologies such as the EndoFLIP may provide more objective criteria in determining the adequacy of myotomy. EndoFLIP facilitates intraoperative assessment of lower oesophageal sphincter distensibility during POEM, enabling the tailoring of myotomies to achieve optimal distensibility while mitigating the risk of postoperative reflux. While modifications to the POEM technique have been shown to maintain efficacy, their impact on reducing the incidence of GORD post-procedure has not been as promising.

The other complications of POEM include mucosal perforation, bleeding, pneumothorax, pneumoperitoneum, pneumomediastinum and subcutaneous emphysema; however, the majority of these can be managed conservatively.

OESOPHAGEAL DIVERTICULA

Oesophageal diverticula may be traction or pulsion diverticula. Most are *pulsion* diverticula that develop at a site of weakness as a result of chronic pressure against an obstruction. *Traction* diverticula are much less common and are a consequence of fibrotic healing of the lymph nodes due to diseases such as tuberculosis or histoplasmosis.

ZENKER'S DIVERTICULUM (PHARYNGEAL POUCH)

Zenker's diverticulum is an acquired pulsion-type pseudodiverticulum that occurs above the cricopharyngeal sphincter through a weak point (Killian's dehiscence) between the oblique and horizontal fibres of the inferior pharyngeal constrictor.

As the pouch enlarges, it leads to halitosis and oesophageal dysphagia. Conventionally, an open left cervical incision under general anaesthesia is performed. The incision is made anterior to the sternocleidomastoid muscle and the carotid vessels retracted laterally. The prevertebral plane is identified and the oesophagus lies anterior to this plane. The diverticulum is identified, dissected and excised using a linear cutting stapler. A myotomy of the cricopharyngeal muscle is performed below the diverticulum. Treatment can also be undertaken endoscopically with two approaches to the dissection: direct incision/stapling of the septal wall along with the mucosa using the rigid or flexible endoscope, or myotomy of the exposed septal wall using the POEM technique with a flexible endoscope (D-POEM).

EPIPHRENIC DIVERTICULA

Epiphrenic diverticula are pulsion diverticula situated in the lower oesophagus above the diaphragm. Histologically, they are pseudodiverticula lacking the muscle layer. Their pathogenesis is considered to be secondary to oesophageal motility disorders and is associated with congenital weakness of the oesophageal wall. More than 75% of epiphrenic diverticula occur concomitantly with oesophageal motility disorders. Therefore, evaluation of oesophageal motility using high-resolution manometry is recommended before deciding on the intervention. The laparoscopic approach is less invasive and is the surgical procedure of choice. The intraoperative picture shows the diverticulum being excised using an endo-linear cutting stapler. Intraoperative endoscopy may also be useful to check the adequacy of the lumen prior to stapling and also to assess the integrity of the staple line after stapling (Figure 8.15).

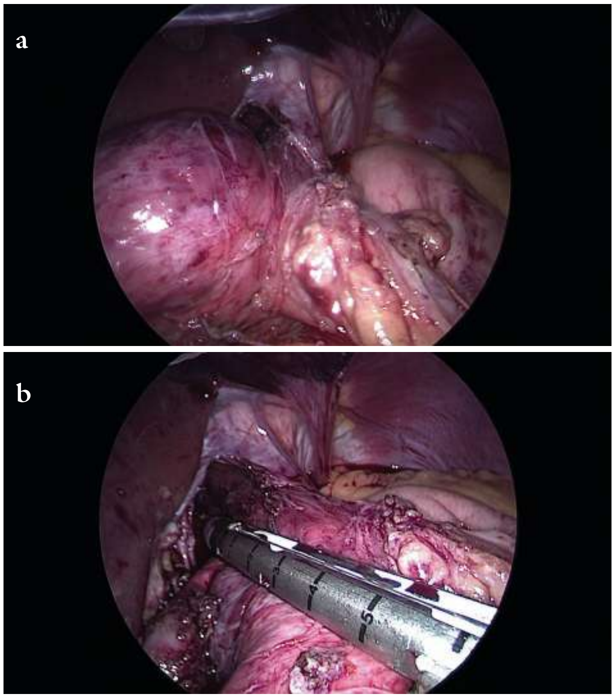
As described above, in addition to diverticulectomy, a myotomy through the lower oesophageal sphincter and an anti-reflux procedure should be added to treat the primary problem and avoid gastro-oesophageal reflux. The long-term outcomes of surgical management are satisfactory.

LEIOMYOMA OF THE OESOPHAGUS

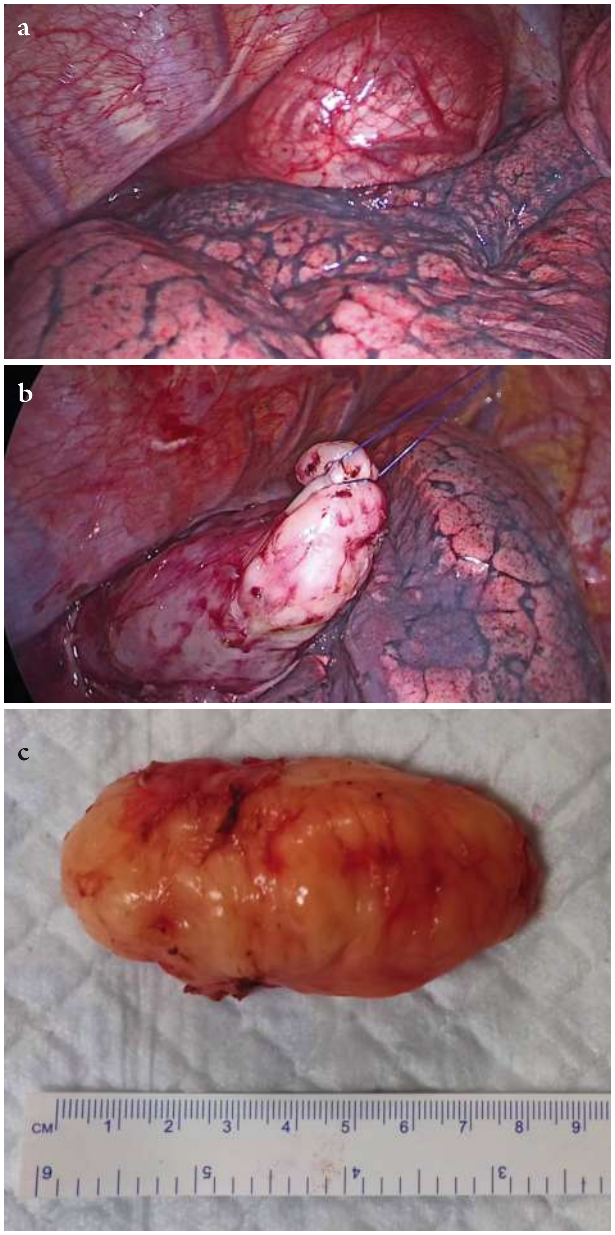
Benign tumours of the oesophagus are uncommon and account for less than 1% of all oesophageal neoplasms. Leiomyomas constitute 70–80% of all such benign oesophageal neoplasms. Other benign oesophageal tumours are rare and include gastrointestinal stromal tumours, granular cell tumours and schwannomas, all of which are rare.

Oesophageal leiomyomas usually occur in patients between 20 and 50 years of age, commonly occurring in the lower two-thirds of the oesophagus. Most patients are asymptomatic, with dysphagia being the most common symptom, followed by chest tightness and pain. The treatment strategy for oesophageal leiomyomas is sequential follow-up of smaller tumours, with surgical resection considered only for larger or symptomatic tumours. The traditional open thoracotomy for enucleation of this tumour has been generally replaced by minimally invasive techniques using video-assisted thoracoscopic surgery (VATS) (Figure 8.16). Upper gastrointestinal endoscopy combined with endoscopic ultrasonographic evaluation of the tumour is mandatory. Most leiomyomas arise from the muscularis propria, with some arising from the muscularis mucosa. A leiomyoma's typical appearance is that of a homogeneous and hypoechoic lesion with clear margin. A contrast enhanced CT scan of the chest can demonstrate the extent of extraluminal involvement of the mass and exclude the possibility of malignancy. Endoscopic biopsy is not recommended because the subsequent mucosal defects or scarring will hamper surgical dissection and reduce the feasibility of enucleation of the tumour. Biopsies are performed only when there are atypical features on endoscopy, or imaging, to rule out malignancy.

VATS is the preferred minimally invasive approach for enucleation of leiomyomas of the oesophagus located above the diaphragm and an abdominal laparoscopic approach for tumours of the lower third of the oesophagus. Open surgical enucleation or even segmental oesophagectomy is still required in some patients with giant oesophageal leiomyomas.



8.15 Laparoscopic stapling of oesophageal epiphrenic diverticulum. (a) Epiphrenic diverticulum. (b) Stapled excision being performed. ⏎



8.16 VATS for a leiomyoma of the oesophagus. (a) Leiomyoma situated below the level of the azygous vein. (b) Enucleation of the leiomyoma. (c) Operative specimen of the excised tumour. ⏎

Some tips and tricks for surgery of oesophageal leiomyomas include the following:

- Regardless of the size, enucleation is tried first. Oesophagectomy is considered only if enucleation fails or if there is a proven malignant tumour.
- Avoid surgery for at least 2 weeks after the patient undergoes endoscopic biopsy, to allow healing of the oesophageal mucosa.
- It is important to identify the correct plane of dissection after incising the outer muscle layer of the oesophagus.
- Intraoperative endoscopy is recommended for localisation of small tumours and for checking the mucosal integrity after enucleation.
- The use of traction sutures in the tumour is recommended to facilitate enucleation.
- If a mucosal tear is identified intraoperatively, immediate suture repair should be performed.
- The oesophageal muscle should be approximated after enucleation to avoid possible motility disorders or pseudodiverticulum formation.

OESOPHAGEAL CYSTS

Oesophageal cysts can be congenital or acquired. Congenital cysts arise from the wall of the foregut during embryonic development. Over time, they fill with mucus and increase in size, causing symptoms of obstruction. Acquired cysts are probably a result of obstruction of the excretory ducts of oesophageal submucosal glands and are found in the lower oesophagus and tend to present later in life.

The complications include obstruction, infection and rupture. Cyst aspiration alone is not adequate because of the risk of recurrence. Surgical resection of the cyst needs to be considered for all patients, whenever possible. If the wall is adherent due to chronic infection, marsupialisation is an option.

OESOPHAGEAL PERFORATION

Oesophageal perforations are one of the most challenging surgical problems and they need to be recognised early and managed agressively. Early recognition and appropriate treatment are the key to successful management. Perforations may be spontaneous (Boerhaave's syndrome), iatrogenic (endoscopic), due to trauma or foreign bodies, or secondary to caustic ingestion.

Boerhaave's syndrome, or spontaneous perforation of the oesophagus, is induced by straining and vomiting. Generally, they have a history of forceful vomiting, but the syndrome has also been reported after weightlifting, coughing and childbirth. Ruptures usually occur in the left posterior aspect of the lower oesophagus and are more frequent in males.

Foreign body perforations result from the ingestion of button batteries, dentures or other objects such as chicken bones. Caustic agents (both acid and alkali) cause severe injury and perforation of the oesophagus. Other conditions such as infection (herpes and HIV) and malignancy can also be associated with perforation.

Presenting features depend on the site of the perforation, the aetiological factors and the time of presentation. The presence of pain in the neck, upper back, chest or abdomen, dysphagia, odynophagia, dysphonia or dyspnoea and fever should raise suspicion of a perforation of the oesophagus. Surgical emphysema is typically seen in cases of upper oesophageal perforations. In cases of delayed presentation, patients may be critically ill and may present with gross sepsis and multiple organ dysfunction syndrome.

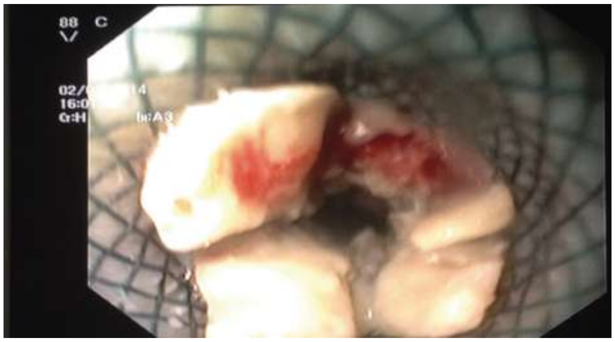
MANAGEMENT

The goals of treatment of any oesophageal perforation include sealing the perforation, early establishment of foregut continuity, drainage of mediastinal/pleural/abdominal sepsis and the establishment of enteral nutritional support. The management can be broadly divided into the following categories:

- Non-operative
- Surgical
- Endoscopic (stents/clips)
- 'Hybrid' techniques

The indications for non-operative management include immediately identified small perforations with no evidence of sepsis in patients whose general condition is unsuitable for operation and in patients with advanced malignancy. Non-operative treatment includes large-bore intravenous access, supplemental oxygen and cardiopulmonary monitoring in a critical care setting. Early institution of broad-spectrum antibiotics, including antifungals, intercostal chest tube drainage and nasogastric decompression should be performed as appropriate. Any signs and symptoms of sepsis during the course of non-operative management warrant consideration of immediate surgical intervention. Respiratory complications such as pneumothorax, mediastinal emphysema and respiratory failure are also indications to consider surgical intervention.

Endoscopic placement of removable covered oesophageal stents are currently being used, with good results reported (Figure 8.17). Stents may be suitable in patients with small leaks and a stable general condition and in early presentation. Stents may also help in iatrogenic perforations or anastomotic leaks or in leaks after previous surgical repair and when there is no associated conduit necrosis. The success rates for stents range from 70% to 80% with the following drawbacks: stent migration (30–50%) and high re-intervention rates (40–50%). Stents are not suitable for cervical perforations, leaks spanning the OG junction and long tears (>6 cm).



8.17 Oesophageal perforation managed by an intraluminal covered stent. ⏎

Endo-Sponge vacuum therapy (Endo-Vac) has been used successfully in large perforations with an associated cavity, where the vacuum therapy helps in promoting early granulation and healing. The drawback is that this treatment needs repeated endoscopy owing to the sponge needing to be changed every few days.

OPERATIVE MANAGEMENT

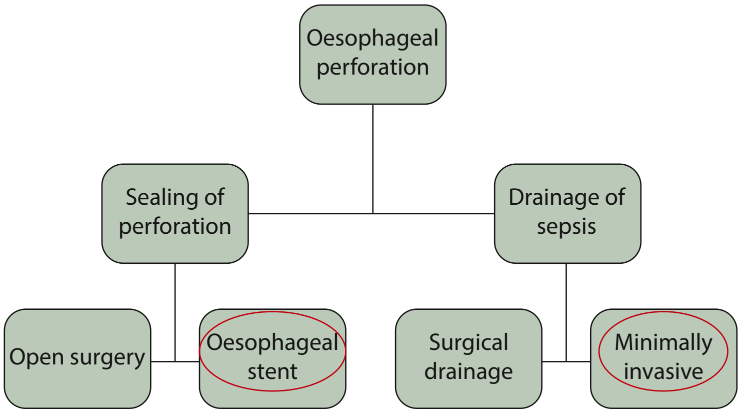
Operative management may be summarised as follows:

- Drainage of septic collections
  - Thoracotomy/laparotomy
  - Minimally invasive techniques
- Closure of perforation
  - Primary repair
    - Facilitated by intraoperative endoscopy
    - Adequate myotomy, proximally and distally
    - Debridement
    - Buttressing using intercostal muscle, pleural flap and/or omentum
  - Repair over T-tube
  - Oesophageal resection
  - Oesophageal exclusion

The surgical procedure selected may depend on the aetiology of the perforation, the time from injury to diagnosis, the site of perforation, whether the leak is contained or non-contained, the general condition of the patient, pre-existing oesophageal disorder (stricture/malignancy) and, of course, the surgeon's experience.

VATS, or open thoracic washout, with decortication may be necessary, depending on the duration of the leak and the amount of pleural soiling. Different procedures that have been described include primary repair with or without reinforcement, repair over a T-tube, an exclusion/diversion operation and single-stage oesophageal resection with or without primary reconstruction.

The management of perforation in a healthy oesophagus is different from that of a perforation occurring in a diseased or obstructed oesophagus.



8.18 Management algorithm for oesophageal perforations. ⏎

Resection of the oesophagus may be warranted in the case of perforation in a diseased oesophagus, whereas primary closure may be feasible in a healthy oesophagus. As a general principle, in all perforations, debridement of non-viable and grossly contaminated tissue is crucial. Primary repair may be possible when the perforation is recognised early (<48 hours) and when there is no gross contamination. Local flaps (pleural, omental, intercostal muscle, diaphragm and pericardium) have been used to buttress the primary repair, with good results. A feeding jejunostomy should be always added, if feasible, for postoperative nutrition.

If primary repair is not possible because of the local tissue friability or because there is severe mediastinitis, oesophageal resection or exclusion and diversion should be considered. Exclusion and diversion comprises cervical oesophagostomy (diversion of the cervical oesophagus and creating a salivary fistula), gastric decompression with a gastrostomy, OG junction stapling and a feeding jejunostomy. Postoperative care should be in a critical care setting with haemodynamic monitoring and with cardiac and respiratory support. A management algorithm for oesophageal perforations is shown in Figure 8.18.

CORROSIVE INJURIES

Corrosive injury to the oesophagus can be caused by either acid or alkali ingestion. Alkali ingestion is more common in Western countries while, in India, acid is generally the more common agent.

PATHOPHYSIOLOGY

Acids cause coagulative necrosis leading to eschar formation, which limits the spread of the agent. Alkalis cause liquefactive necrosis and saponification of the tissues associated with thrombosis of the vessels. This leads to higher penetration of the alkali and proportionally higher tissue damage.

CLINICAL PRESENTATION

The clinical features of the injury depend on the physical form of the substance ingested (solids vs liquids), the specific substance, the quantity and concentration, and the duration of tissue contact. The symptomatology can be broadly divided into two phases: the acute phase and the chronic phase.

The acute phase includes the initial post-injury period, wherein the patient can present with oral and substernal pain, hypersalivation, odynophagia, dysphagia, vomiting and haematemesis. These symptoms gradually resolve as injuries heal and fibrosis develops. Patients in the chronic phase of corrosive injury present with dysphagia secondary to either oesophageal strictures or disruption of the swallowing mechanism.

ENDOSCOPIC EXAMINATION

Current recommendations state that, if indicated, upper gastrointestinal endoscopy in the acute setting should be performed by a senior endoscopist, within 12–48 hours after the ingestion of the agent. Gentle insufflation, adequate sedation and caution are mandatory to avoid an iatrogenic perforation of the friable oesophagus. Endoscopy is contraindicated if there is any suspicion of perforation. The endoscopic classification of caustic injuries proposed by Zargar et al. (1989) has been shown to have prognostic significance.

IMAGING

Imaging options include plain films and CT scans. Plain X-rays are indicated to rule out pneumoperitoneum. CT scan of the thorax/abdomen should be done if there is any doubt or inconclusive plain X-ray radiology. CT scans of the thorax can provide detailed evaluation of the injuries. A grading system has been proposed for caustic lesions of the oesophagus (Contini and Scarpignato, 2013).

MANAGEMENT

There are three broad phases during the management of a corrosive injury: the early, intermediate and chronic phases. The early phase of management includes immediate assessment of the extent of injury, resuscitation and a plan on further care of the acute episode. The intermediate phase is concerned with managing the acute episode in hospital and deals with the issues of sepsis, aspiration and nutrition. The chronic phase deals with management of long-term sequelae of corrosive ingestion including strictures and swallowing dysfunction.

Management of the chronic phase

The most common late sequela of corrosive ingestion is the formation of strictures. Strictures usually develop within 8 weeks of ingestion, but can develop as early as 3 weeks or as late as 1 year. Dilatation of the strictures can be safely commenced from the fourth week. Both balloon dilators and Savary-Gilliard dilators have been used. Reconstructive surgery for strictures secondary to corrosive ingestion should be delayed for at least 6 months after injury to allow for complete scar formation and for adequate recovery from the acute insult.

Surgery for chronic strictures

Resection or bypass? Patients with short segment strictures of the stomach, most commonly of the antrum and pyloric region, are treated with a resection procedure with re-establishment of continuity. Resection procedures for the oesophagus can be technically challenging due to dense peri-oesophageal adhesions. There is a risk of injury to the great vessels, trachea, thoracic duct or vagus nerve, thus significantly increasing morbidity. Therefore, bypass procedures are usually done via the substernal route using either a colonic or a gastric conduit. The proposed drawbacks of bypass, as opposed to resection, include persistent acid reflux into the oesophagus, cystic dilatation of the oesophagus and an increased risk of malignancy within the damaged oesophagus. It should be noted that the risk of malignancy is often overstated in the literature.

Stomach or colon for a bypass procedure? A critical choice for a bypass procedure is the conduit that is used for the interposition graft. Gastric pull-up is technically easier and requires only one anastomosis. A colonic conduit, on the other hand, requires multiple anastomoses and extensive dissection. However, in caustic injury, when the stomach itself may be scarred, a colonic graft may be a better choice. The left colon is preferred to the right due to its smaller diameter, more constant and reliable blood supply (from the left colic artery), adequate length for total oesophageal replacement and superior ability to propel a solid bolus. In rare cases when both the stomach and the colon cannot be used, a jejunal graft could also be used, most often as a free flap of jejunum.

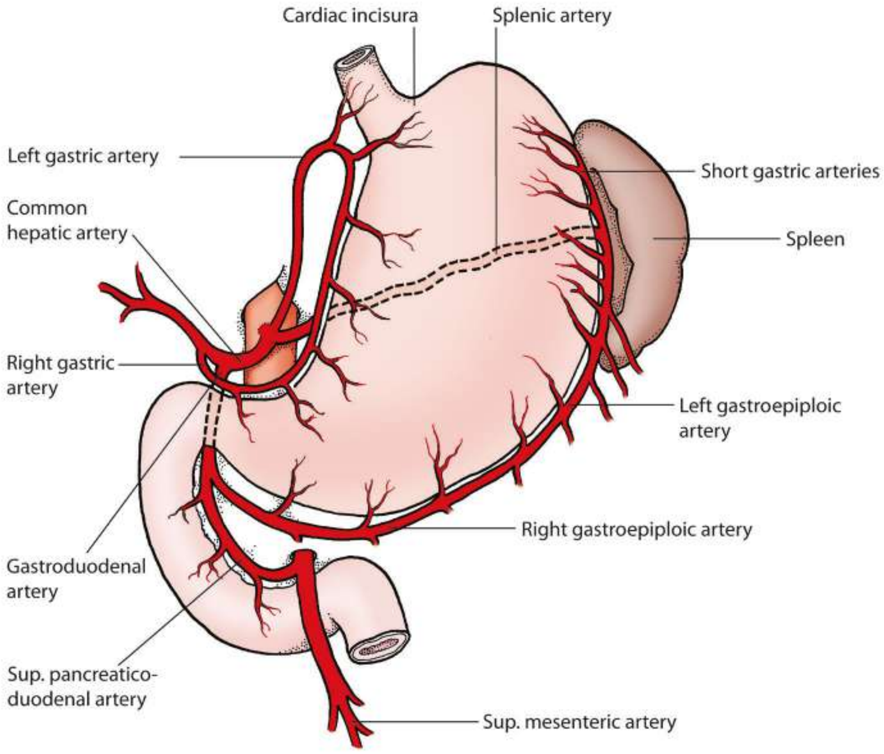
High corrosive strictures or strictures involving the pharynx offer more challenges in their management due to the difficulty of restoring swallowing without creating intractable aspiration. Laryngeal involvement in this subset of patients presents with dysphonia and may require an elective tracheostomy.

Role of tracheostomy and laryngectomy Assessment and management of the airway remains an integral part of the management of patients with corrosive ingestion. In the acute phase, tracheostomy may be indicated in patients with respiratory distress due to corrosive-induced laryngeal oedema. In the chronic phase, tracheostomy can be either temporary or permanent based on the location of the anastomosis and the need for a laryngectomy.

Oesophageal conduits There are various conduits that can be used to replace the oesophagus when extensive resection has been necessary. These are discussed in more detail in Chapter 9.

ANATOMY OF THE DUODENUM

The duodenum commences at the pylorus. After the first 2–3 cm, the duodenum loses much of its peritoneal covering and becomes a retroperitoneal, relatively fixed, segment of the small bowel as far as the duodenojejunal flexure, where the bowel again becomes mobile on a mesentery. The duodenum is curled around the head of the pancreas so that its *first part* lies horizontally above it, the *second part* vertically to its right and the *third part* horizontally below it. The *fourth part* then ascends to the left of the aorta. The bile and pancreatic ducts enter the concave medial wall of the second part of the duodenum at the *ampulla of Vater*. The duodenum is intimately related to the hilum of the right kidney, the hepatic flexure of the colon and the aorta, in addition to the pancreas. Thus, the duodenum is a landmark during


Cardiac incisura
Splenic artery
Left gastric artery
Short gastric arteries
Common hepatic artery
Spleen
Right gastric artery
Left gastroepiploic artery
Right gastroepiploic artery
Gastroduodenal artery
Sup. pancreatico-duodenal artery
Sup. mesenteric artery

8.19 Arterial supply to the stomach and proximal duodenum. ⏎

many intra-abdominal dissections and must often be mobilised during pancreaticobiliary, renal and aortic surgery.

ARTERIAL SUPPLY

The duodenum is supplied from both the coeliac axis and the superior mesenteric artery (Figure 8.19). The superior pancreaticoduodenal artery, the inflow of which is from the coeliac axis, and the inferior pancreaticoduodenal branch of the superior mesenteric artery form an arcade around the head of the pancreas. Most of the arterial supply to the duodenum is from this arcade, although there are additional branches that cross the pylorus, to the first part of the duodenum, from the gastric and gastroepiploic arteries.

PEPTIC ULCER DISEASE

Peptic ulcers result from an imbalance between gastric acid secretion and the ability of the mucosa to withstand the autodigestion. About 90% of peptic ulcers are related to *Helicobacter pylori* infection. In the other 10%, the aetiology may include drugs (non-steroidal anti-inflammatory drugs [NSAIDs]/corticosteroids), alcohol abuse, smoking and abnormal acid secretion (Zollinger–Ellison syndrome).

HISTORICAL PERSPECTIVE

Elective operations for peptic ulcers were among the most common procedures performed by the general surgeon in the middle decades of the last century. The original operations of Billroth I gastrectomy and gastroenterostomy alone were replaced by the Polya gastrectomy and, later, to a greater extent, by vagotomy and drainage procedures. A gastrectomy reduced acid both by the removal of a portion of the parietal cell mass and by the excision of the gastrin-producing antrum, thus reducing stimulation of the remaining parietal cells. Vagotomy abolished vagal stimulation of the parietal cell mass. A vagotomy with antrectomy was probably the most effective operation, but it was associated with the side effects of both a truncal vagotomy and a partial, albeit limited, gastrectomy. Debate regarding the best operation for peptic ulceration focused on the balance between the incidence of recurrent ulceration and the incidence and severity of side effects.

The whole situation changed with pharmacological advances. As the operations were designed to reduce acid secretion of the stomach, their role became increasingly unimportant as more potent antisecretory drugs became available. The identification of *Helicobacter pylori* as a causative agent, combined with effective regimes for its eradication, further changed surgical practice. The majority of patients could be cured by medical treatment and did not require long-term acid suppression. The elective management of peptic ulcer disease is now almost exclusively medical. H_2 receptor antagonists, or proton-pump inhibitors, are used to block acid secretion, and *Helicobacter* is eradicated with antibiotics.

Surgery is now mainly confined to the management of the complications of peptic ulcer disease, including perforation, haemorrhage and gastric outlet obstruction. Despite decreasing incidence, peptic ulcer perforation and haemorrhage are still major causes of morbidity and mortality. Surgery is also occasionally indicated for ulceration refractory to medical treatment and for the complications of previous peptic ulcer surgery.

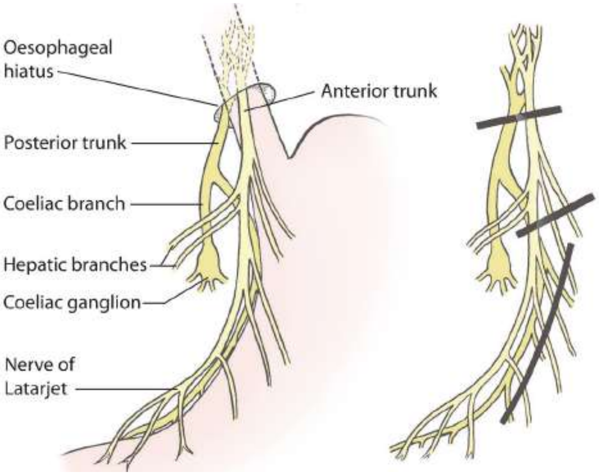
The current indications for surgical intervention in peptic ulcer disease are limited to:

- Bleeding
- Perforation
- Stenosis with gastric outlet obstruction
- Intractability or failed medical therapy (uncommon in the era of effective medical therapy)
- Risk of malignancy (in gastric ulcers)

The choice of surgical intervention for intractable duodenal ulcer disease includes either a vagotomy with or without a drainage procedure or a gastric resection.

VAGOTOMY

Vagotomy results in the elimination of the cholinergic stimulus for acid secretion and renders the acid-producing parietal cells less responsive to gastrin stimulus. There are three types of vagotomies: truncal, selective and highly selective (Figure 8.20).



8.20 Vagal innervation of the stomach. The three bars indicate the level of transection in truncal vagotomy, selective vagotomy and highly selective vagotomy. ⏎

TRUNCAL VAGOTOMY

Truncal vagotomy involves division of the anterior and posterior vagal trunks, after they emerge through the diaphragmatic hiatus. Acid secretion is drastically reduced because of diminished cholinergic stimulation of parietal cells, and the cephalic phase of gastric secretion is essentially eliminated.

Truncal vagotomy results in decreased gastric motility, and emptying, as the antral and pyloric branches are compromised. Therefore, along with a truncal vagotomy, a drainage procedure will be necessary. As the division is proximal to the hepatic branch of the anterior vagus (gallbladder and bile duct motility), this can predispose to gallstone formation. Division of the vagus proximal to the coeliac branch of the posterior vagus (small intestine motility) may result in diarrhoea and dumping.

SELECTIVE VAGOTOMY

Selective vagotomy involves division of the vagus distal to the take-off of the hepatic and coeliac branches. This results in sparing of the innervation to the gallbladder and small intestine. Therefore, gallstones, dumping and diarrhoea are not encountered. However, a drainage procedure is still required because the vagal pyloric innervation is eliminated.

HIGHLY SELECTIVE VAGOTOMY

Highly selective vagotomy (HSV) is also known as parietal cell vagotomy or a proximal cell vagotomy. The operation involves the division of all of the branches of the vagus nerve along the lesser curvature that innervate the body and fundus of the stomach, while preserving the hepatic and coeliac branches, as well as the distal vagal branches extending to the antrum and pylorus. The aim of HSV is to eliminate the vagal stimulation to the acid-secreting portion of the stomach without interrupting motor innervation to the antrum and pylorus.

Various modifications of HSV have been described:

- Posterior truncal vagotomy with an anterior HSV (Hill–Barker procedure)

- Posterior truncal vagotomy with anterior lesser-curve seromyotomy (Taylor procedure). This is usually done as a laparoscopic procedure (see Figure 8.21)

SURGICAL STEPS OF A TRUNCAL VAGOTOMY

The surgery can be open or performed laparoscopically.

Entrance into the peritoneal cavity

An upper midline incision, above the umbilicus, is extended superiorly to the xiphoid process. The peritoneal cavity is opened and inspected. A self-retaining retractor is placed in the abdomen for exposure, and a liver retractor is placed to facilitate access to the lesser curvature and diaphragmatic hiatus.

Distal oesophageal mobilisation

The assistant retracts the greater curvature inferiorly to expose the GOJ. The peritoneal covering of the GOJ is incised and the oesophagus is encircled with a Penrose drain. The oesophagus should be mobilised for a distance of 4 to 5 cm above the GOJ. If the left lobe of the liver obstructs exposure, the left triangular ligament may be divided.

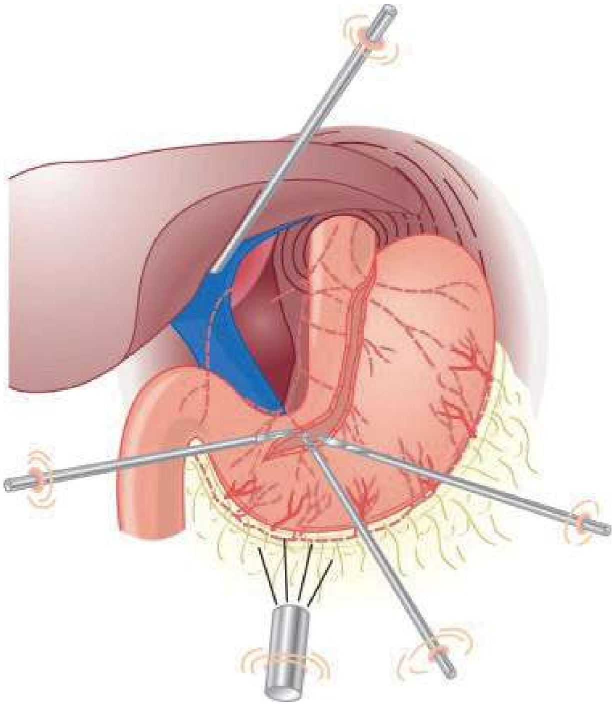
Identification and division of the anterior vagal trunk

A single vagal trunk is identified, typically 2 to 4 cm superior to the GOJ. The nerve is mobilised for a minimum of 2 cm. The trunk is then clipped and divided proximally and distally, resulting in a minimum resected specimen of 2 cm.

Identification and division of the posterior vagal trunk

The oesophagus is now retracted anteriorly to the patient's left side. The posterior trunk is identified along the right edge of the oesophagus. The nerve is mobilised for a minimum of 2 cm. The trunk is then clipped and divided proximally, and distally, with medium clips, resulting in a minimum resected specimen of 2 cm.

Pathological confirmation via frozen section is used by some surgeons to confirm vagotomy. Drainage procedures include gastroenterostomy, pyloroplasty (Heineke–Mikulicz, Finney or Jaboulay) or a pyloromyotomy.



8.21 Laparoscopic Taylor procedure. (From Dubois[4], with permission of John Wiley & Sons.) ⏎

LAPAROSCOPIC TAYLOR PROCEDURE

Although most types of vagotomies have been performed laparoscopically, the Taylor procedure (anterior seromyotomy with posterior truncal vagotomy) is technically the most suitable for the laparoscopic approach (Suraj and Samarasam, 2019) (Figure 8.21).

DRAINAGE PROCEDURES

If a truncal or selective vagotomy is performed, some form of gastric drainage procedure is added to avoid gastric stasis. Drainage procedures divide or bypass the pyloric sphincter mechanism in order to facilitate gastric emptying. The two common drainage procedures are pyloroplasty and gastrojejunostomy. Pyloroplasty is preferred to gastrojejunostomy because the normal anatomical relationship between the stomach and the duodenum is preserved.

The prelude to any type of pyloroplasty is adequate mobilisation of the second part of the duodenum by full Kocherisation. In this manoeuvre, a peritoneal incision is made lateral to the second part of the duodenum to enter the areolar plane behind the duodenum and pancreatic head. As the dissection in this plane is continued towards the midline, the duodenum and pancreas can be lifted forwards off the kidney and inferior vena cava.

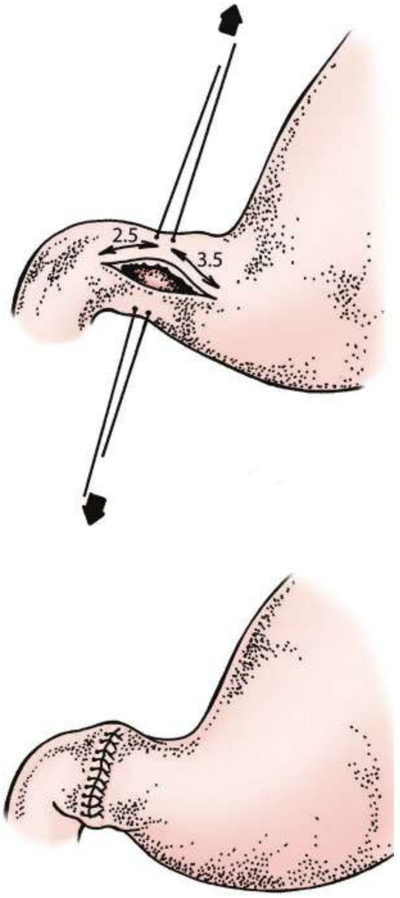
- Pyloroplasty
  - Heineke–Mikulicz pyloroplasty

  - Finney pyloroplasty
  - Jaboulay gastroduodenostomy
- Gastrojejunostomy

Heineke–Mikulicz operation

The Heineke–Mikulicz operation has undergone several modifications since its original description, but it is in essence a longitudinal incision across the pylorus that is then closed transversely. Two deep stay sutures are inserted 1 cm apart in the anterior aspect of the pyloric ring. A 6 cm longitudinal incision is then made between the sutures into the lumen. Traction on the stay sutures converts the longitudinal incision into a diamond-shaped opening, which is closed transversely using a single layer of interrupted absorbable sutures, such as 3/0 polydioxanone (PDS®) (Figure 8.22). Further layers of sutures, as originally described, are no longer recommended, as they narrow the pyloric channel. The pyloroplasty may then be buttressed with a patch of omentum.

This operation is not feasible if the pylorus is grossly thickened or scarred. The operation can be carried out at open surgery or laparoscopically.



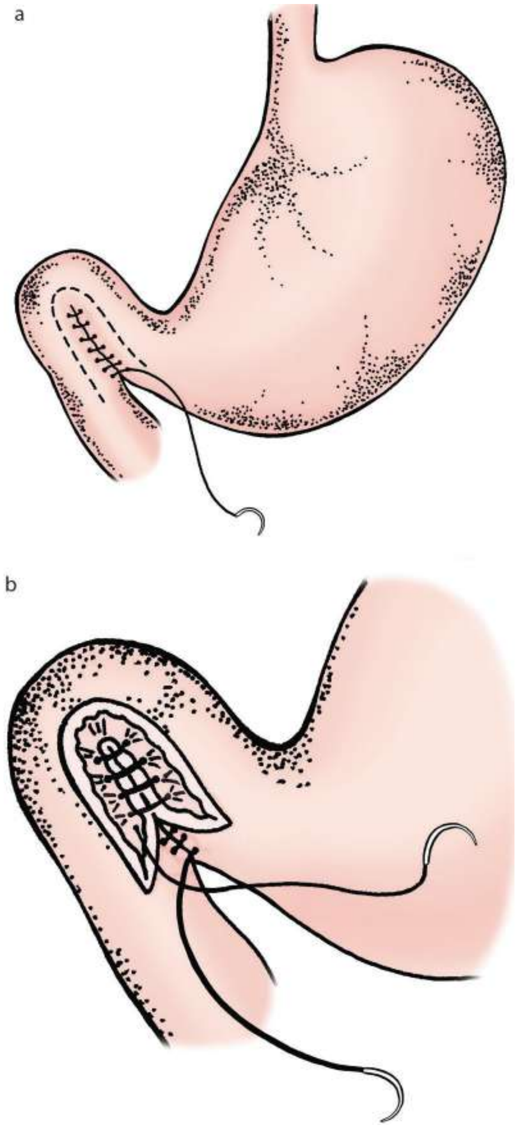
8.22 Heineke–Mikulicz pyloroplasty. ⏎

Finney pyloroplasty

Although often described as a pyloroplasty, Finney pyloroplasty is really a gastroduodenostomy (Figure 8.23). Its only advantage over a Heineke–Mikulicz operation is that it is still a possible option when scarring is more severe. However, in these circumstances, most surgeons would opt for a gastroenterostomy.

Pyloric dilatation and pyloromyotomy

The pyloric sphincter mechanism can also be disrupted by *pyloric dilatation* or can be formally divided



8.23 Finney gastroduodenostomy. (a) A posterior seromuscular suture is inserted before an inverted U-shaped incision is made. (b) The posterior all-layer suture has been started. It will be continued round anteriorly to close the opening into the lumen. The posterior seromuscular suture is then carried round over this all-layer suture. ⏎

by *pyloromyotomy*, in which the muscle is incised longitudinally but the mucosa is preserved intact. These are options employed to improve drainage from the intrathoracic gastric conduit used for reconstruction after oesophagectomy.

Gastrojejunostomy

A gastrojejunostomy involves the anastomosis of a loop of proximal jejunum to the stomach. This may be used as a drainage procedure in conjunction with a vagotomy or as a bypass for a gastric outlet or duodenal obstruction. The most frequent causes of obstruction are malignancy and chronic peptic ulcer disease and, in these patients, preoperative correction of hypoalbuminaemia and electrolyte imbalances have been shown to correlate with a reduction in morbidity and mortality.

The anastomosis is a side-to-side anastomosis between a dependent portion of the stomach and the proximal jejunum. The opening in the stomach can be horizontal, oblique or vertical and, according to the direction of the jejunal loop, may be described as isoperistaltic or antiperistaltic. There appears to be no specific advantage of one configuration over another. The anastomosis can be in front of the transverse colon, when it is described as an anterior or antecolic gastroenterostomy, or behind the transverse colon, when it is described as a posterior or retrocolic gastroenterostomy (Figure 8.24). When the distal stomach and pylorus have been excised and an anastomosis to the duodenum as a Billroth I reconstruction is not possible, a loop of jejunum is brought up for a Billroth II reconstruction. This anastomosis is in essence another form of gastroenterostomy.

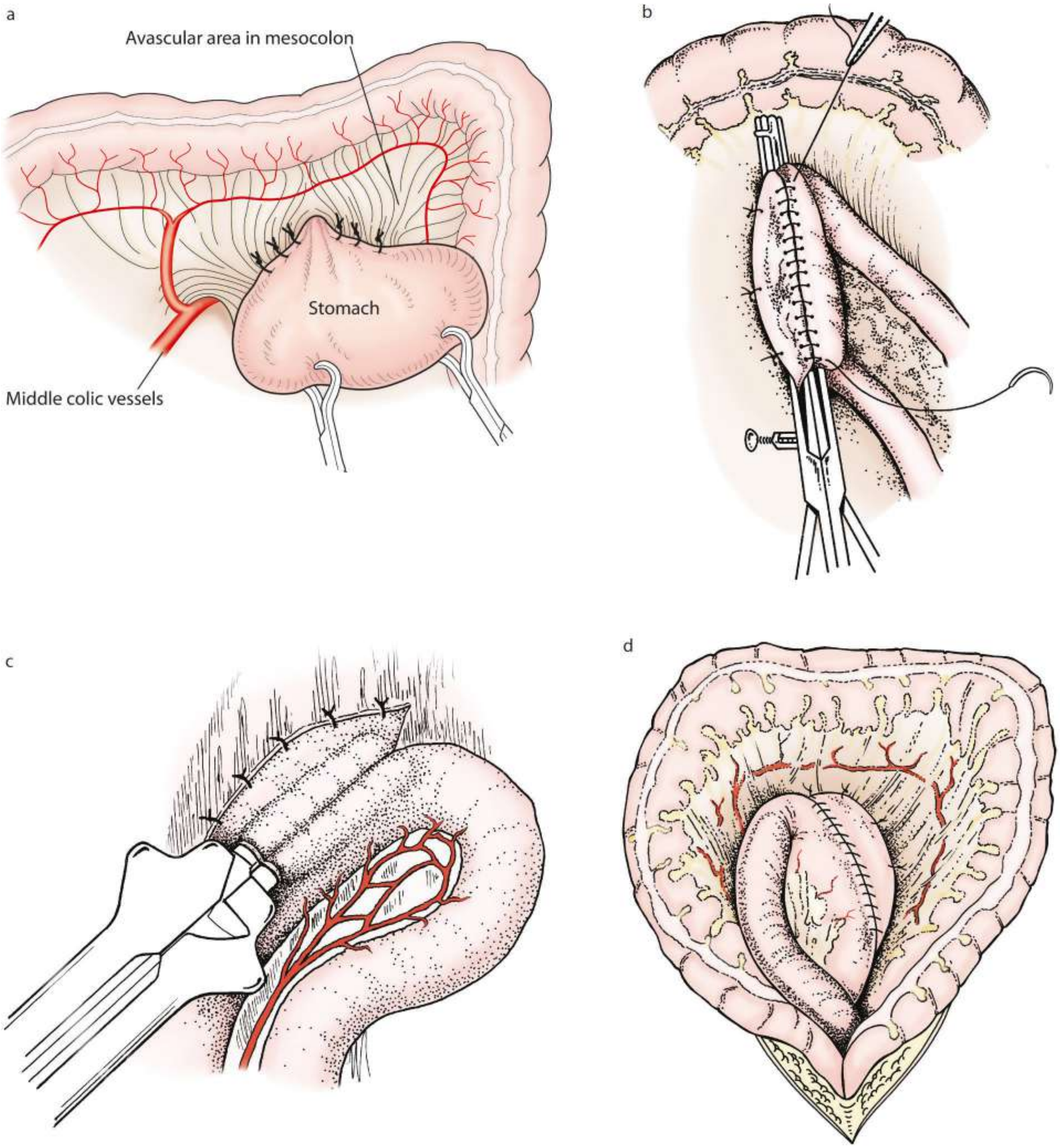
Open gastroenterostomy A *posterior (retrocolic) anastomosis* is often favoured, as it may offer better function. The omentum and transverse colon are lifted up and the duodenojejunal flexure and the first jejunal loop are identified. The anastomosis can usually be made to the segment between 10 and 20 cm from the duodenojejunal flexure, but it must reach the stomach without tension. A window is created in the transverse mesocolon through an avascular area, usually to the left of the middle colic vessels, taking care not to damage them. A dependent part of the gastric antrum is then brought through the mesocolic window using atraumatic Babcock forceps (Figure 8.24a). Full-thickness posterior stitches are placed using absorbable sutures with the first knot placed outside the lumen of the stomach and the jejunum. The posterior and anterior segments of the anastomosis are sutured using Connell stitches, which are running horizontal mattress stitches (Figure 8.24b). The anterior outer layer is then oversewn using Lembert stitches in the seromuscular layer. In a retrocolic anastomosis, the margins of the defect in the mesocolon are sutured to the stomach in order to prevent herniation of the small intestine through the mesocolic window (Petersen's hernia).

Stapled techniques are similar except the stapler is used to approximate the jejunum and the stomach rather than suture, and the gastrostomy and jejunostomy only need to be able to pass the stapler into the lumens (Figure 8.24c). The gastrostomy and jejunostomy sites can then be closed with suture or an additional firing of the staple gun.

In obese patients with a short thick mesocolon and a relatively fixed stomach, a conventional hand-sewn posterior gastroenterostomy can prove difficult. In this event, access into the lesser sac by separating the greater omentum from the transverse colon allows the selected loop of jejunum to be drawn upwards through a window in the transverse mesocolon. Anastomotic clamps can then be applied and the anastomosis performed with relative ease above the transverse colon. On completion, the anastomosis is drawn down through the window in the mesocolon and the edges of the mesocolic window are sutured to the stomach. The final alignment of the anastomosis is thus identical to that illustrated in Figure 8.24d.

Laparoscopic gastroenterostomy The position of the ports varies with the surgeon's preference but, in general, an initial umbilical port will be chosen followed by a 10 mm working port in the left hypochondrium and a 5 mm port at the xyphisternum. Additional working ports can be inserted, if required, at any stage. An *antecolic anastomosis* is often favoured laparoscopically for technical reasons.

The segment of jejunum to be used is identified and intracorporeal stay sutures are inserted for aligning the bowel segments. These sutures provide control of the segments being united and also allow them to be elevated, thereby improving access and reducing spillage. The stomach and the antimesenteric border of the jejunum are then opened using laparoscopic diathermy scissors or an ultrasonic scalpel. The length of these enterotomies should only be sufficient to accommodate the stapling device. A laparoscopic intestinal stapling device is then inserted through the 12 mm port and a limb of the stapler is manoeuvred through each of the enterotomies. The device is then closed and fired (Figure 8.25). It is important to check that the hilt of the endoscopic gastrointestinal anastomotic stapling device is snug to the enterotomies before firing to ensure an adequate opening. The enterotomies themselves may be closed by laparoscopic intracorporeal suturing. Care must be taken to avoid narrowing the opening at this stage. The stay sutures are removed and the stomach insufflated via the nasogastric tube to look for any leakage. The greater omentum can be placed over the anastomosis.



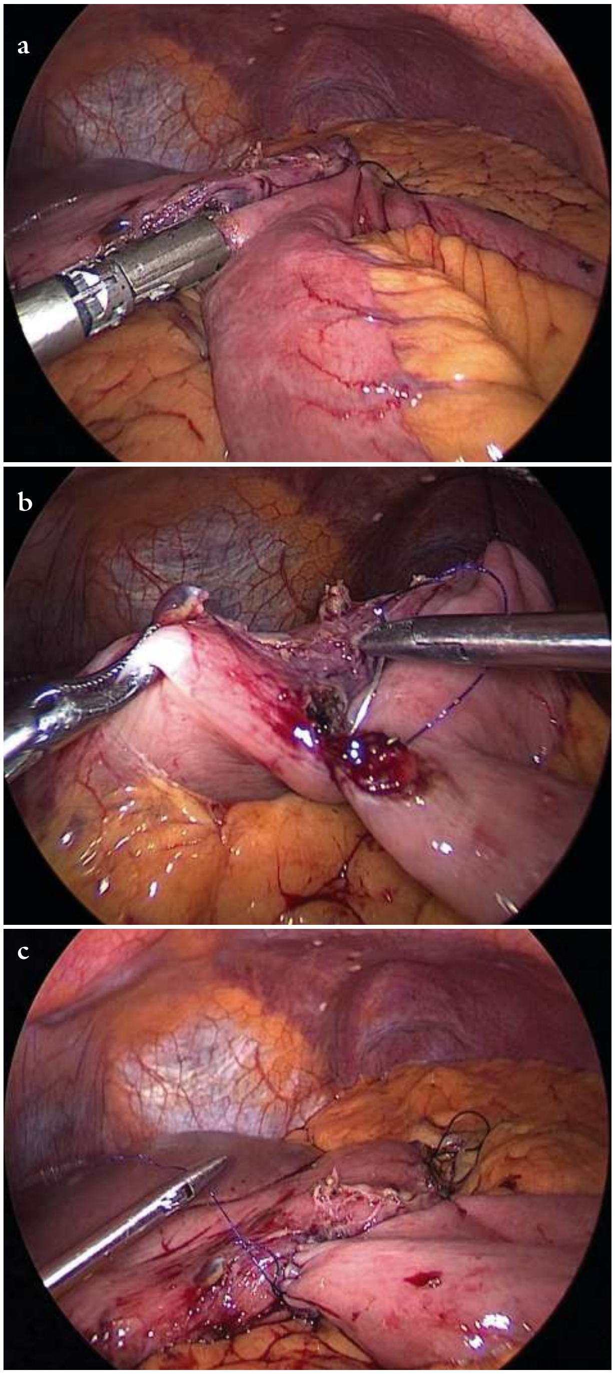
8.24 Retrocolic gastroenterostomy. (a) Gentle manipulation of the stomach through the window in the transverse mesocolon using atraumatic Babcock forceps. (b) The classical hand-sewn anastomosis. (c) The alternative stapled anastomosis. (d) A completed oblique isoperistaltic anastomosis lying below the transverse mesocolon; the mesocolic window has been closed. ⏎

Roux loop

An alternative form of gastroenterostomy is the anastomosis of a Roux-en-Y loop of jejunum to the stomach, as an end-to-side anastomosis rather than the classical side-to-side gastroenterostomy. A Roux loop has the advantage of less biliary reflux. This is a particularly appropriate method of gastric drainage when there is only a small residual proximal stomach remnant, whether after gastric resection for cancer or a gastric exclusion operation for morbid obesity.

Management of gastric ulcers

Unlike duodenal ulcers, gastric ulcers have to be approached with caution in view of the associated risk of malignancy. Therefore, they have to be biopsied



8.25 Laparoscopic gastrojejunostomy. (a) Endo-linear cutting stapler inserted through the gastrotomy and enterotomy for stapling. (b) Closure of the enterotomy after stapler firing. (c) Completed gastrojejunostomy. ⏎

to rule out malignancy and, unlike duodenal ulcers, should be excised as part of treatment. Acid hypersecretion may not be associated with some types of gastric ulcers. The modified Johnson classification system is based on anatomical location and acid-secretory potential and provides a useful basis for considering operative treatment of gastric ulcers (Figure 8.26 and Table 8.1).

Table 8.1 The modified Johnson classification system for gastric ulcers ⏎

Type of gastric ulcer	Location	Acid secretion
Type I	Lesser curvature	Low
Type II	Body of stomach and duodenum	High
Type III	Prepyloric ulcer	High
Type IV	High lesser curvature ulcer	Low
Type V	Anywhere, induced by medication	Low

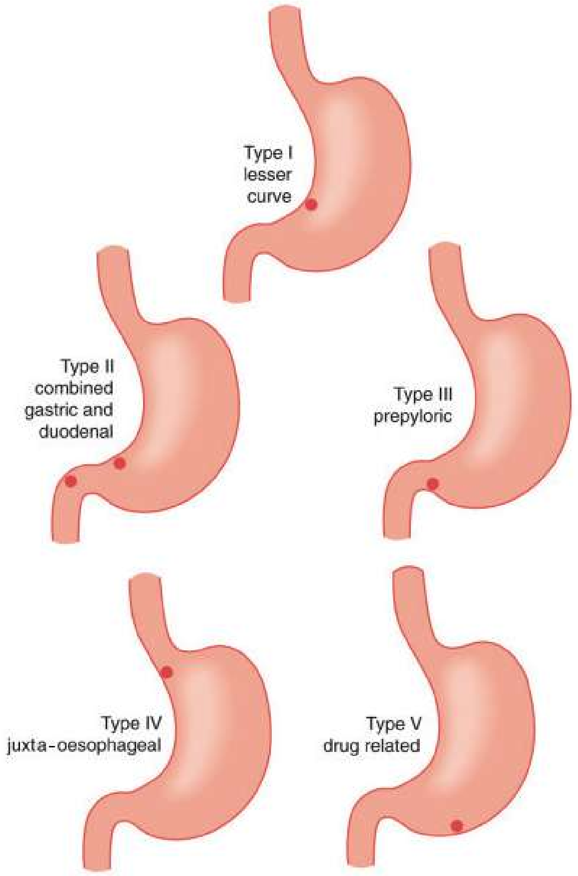
Table 8.2 Operations for gastric ulcers based on the modified Johnson classification ⏎

Type of gastric ulcer	Operation
Type I	Antrectomy and Billroth I reconstruction
Type II	Truncal vagotomy and antrectomy/ HSV
Type III	Truncal vagotomy and antrectomy
Type IV	If the ulcer is within 2 cm of the GOJ, Kelling–Madlener/Csendes procedure If the ulcer is >2 cm from the GOJ, Pauchet procedure
Type V	Stop medications/excision and truncal vagotomy

Table 8.2 and Figure 8.27 show the surgical therapy for intractable gastric ulcers based on the modified Johnson classification.

GASTRECTOMY

Total and subtotal gastrectomy in the context of malignancy is discussed in Chapter 9. Gastrectomy is sometimes also necessary for benign disease and, in this context, a partial gastrectomy (either proximal or distal) may be appropriate. Various reconstruction techniques are possible including Billroth I, Billroth II or Polya gastrectomy or Roux-en-Y reconstruction. After a distal partial gastrectomy, a gastroduodenal anastomosis is described as a Billroth I gastrectomy (Figure 8.28a). If instead the duodenum is closed and the first loop of jejunum is brought up for the anastomosis, this is described as a Billroth II gastrectomy (also referred to as a Polya gastrectomy) (Figure 8.28b). Although the two operations were initially considered slightly different, the names are now usually used synonymously. A further alternative reconstruction is with a Roux-en-Y loop (Figure 8.28c), as discussed in Chapter 9. Total or subtotal colectomy for benign disease does not require radical lymphadenectomy.



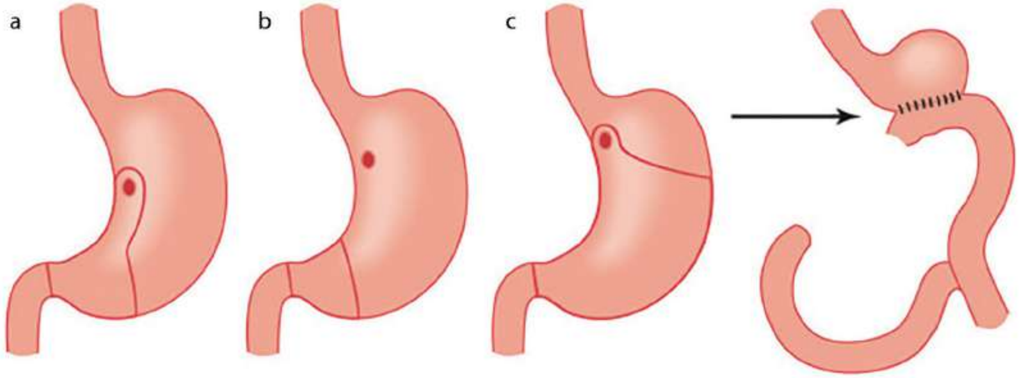
8.26 Classification of gastric ulcers based on their anatomical location. (From Matthews and Silen[14], with permission of Elsevier.) ⏎

Billroth I gastrectomy

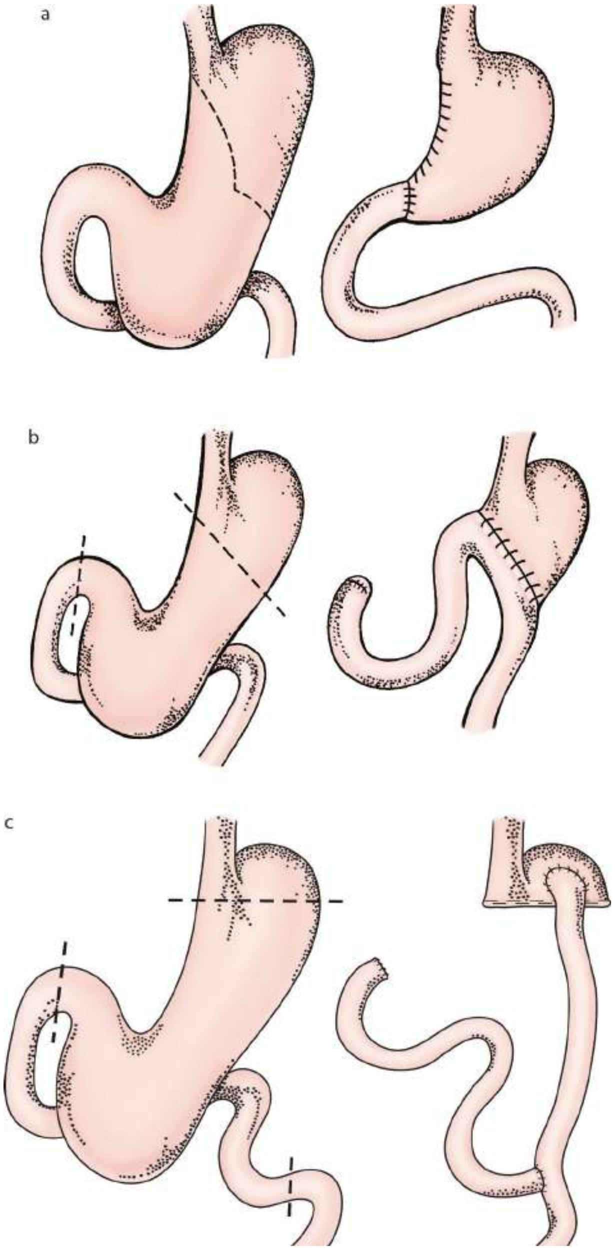
Professor Hans Theodore Billroth described his first gastric resection operation for malignancy in 1881. A Billroth I gastrectomy involves removal of a distal gastric segment, followed by primary anastomosis with preservation of duodenal integrity. Nowadays, the classic Billroth I gastrectomy is an operation that is almost entirely reserved for benign pathology, as, in the standard operation, only a very limited lymphadenectomy is achieved. However, surprisingly, this method of reconstruction is still possible after a radical partial gastrectomy and lymphadenectomy, as there has been extensive mobilisation of the remnant tissues. The advantage of a Billroth I gastrectomy compared with a Billroth II (Polya) procedure is the maintenance of the physiological and anatomical gastroduodenal pathway. Thus, it offers a lower incidence of post-gastrectomy syndromes, minimal disturbance of pancreatic function and a possible lower incidence of late development of carcinoma in the stomach remnant.

Operative procedure The abdomen is usually opened by a midline laparotomy incision, although some surgeons prefer a right paramedian or a bilateral subcostal incision. A Balfour retractor should provide adequate access but, for very obese patients, Goligher-type bars or an Omni-Tract retractor system may improve access. The stomach and greater omentum are drawn out of the wound and retracted inferiorly by the assistant.

Starting close to the pylorus, the greater omentum is detached from the stomach. With benign disease, the plane of dissection may be between the stomach and the gastroepiploic vessels, with ligation of only the gastric branches of the arcade (Figure 8.29a). Preservation of the gastroepiploic vessels ensures the viability of the greater omentum and may also provide additional blood supply beyond the limits of the



8.27 Operations for a type IV gastric ulcer. (a) Pauchet procedure. (b) Kelling–Madlener procedure. (c) Csendes procedure (oesophagogastrojejunostomy). (Modified from Seymour[24], with permission of Elsevier.) ⏎



8.28 Diagrammatic representation of modes of reconstruction after partial gastrectomy. (a) Billroth I. (b) Billroth II or Polya. (c) Roux-en-Y loop. ⏎

gastric resection, ensuring a healthy anastomosis. Avascular adhesions between the stomach and pancreas are divided. Occasionally, a posterior gastric ulcer may extend into the pancreas, and this requires careful dissection, ensuring haemostasis.

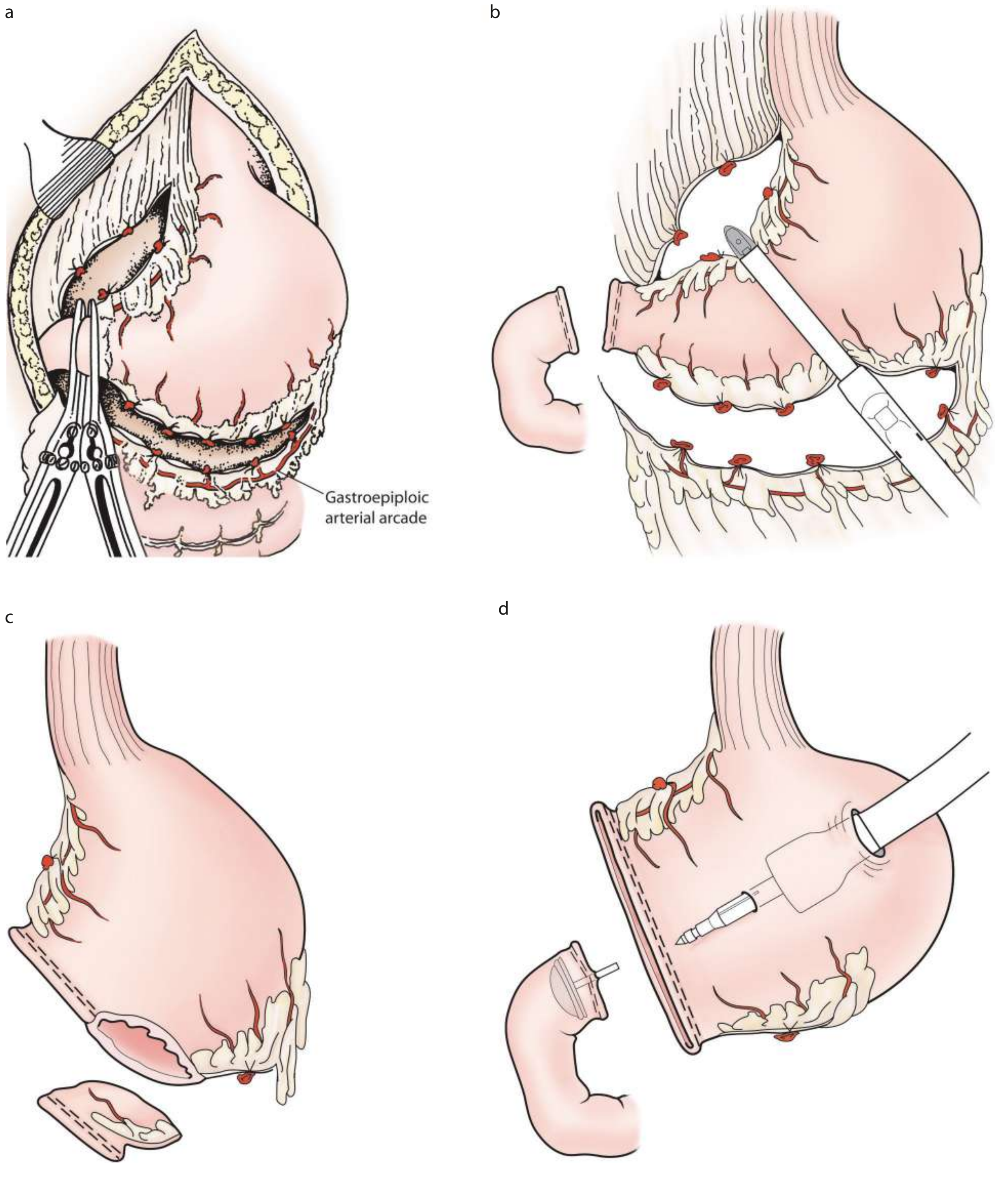
The lesser omentum is then incised in its avascular plane outside the gastric arcade, allowing identification of the right gastric artery. The right gastric artery may be represented by several vessels rather than a single trunk, whereas the left gastric artery is almost always represented by a single, usually substantial, vessel. The right gastric artery is ligated and divided. Division of the lesser omentum continues parallel with the lesser curve. In benign disease, the descending branch of the left gastric artery can usually be preserved and ligated after it has given its first branches to the lesser curve, so that the gastric remnant receives additional blood supply from the proximal portion of the left gastric artery. The stomach is lifted forwards and the inferior border of the first part of the duodenum is separated from the pancreas, carefully dissecting and ligating small vessels.

Kocherisation of the duodenum will facilitate the anastomosis and reduce tension at the suture line. The duodenum beyond the proposed resection line must be inspected to ensure that it is healthy and of sufficient calibre for the gastroduodenal anastomosis. The duodenum is then divided between two non-crushing clamps (Figure 8.29a) or with a linear cutting stapling device.

The line for the gastric resection is determined and the stomach divided with a linear stapler (Figure 8.29b). This may require firing twice to divide the whole way across. Many surgeons elect to oversew the staple line in order to ensure haemostasis. A clamp is then applied at an angle to the original stapled closure at the greater curve and a segment removed to correspond to the duodenal lumen (Figure 8.29c). When stapling devices are unavailable, these two manoeuvres can be performed by applying clamps at an angle to each other. The stomach is divided with a scalpel close to the clamps. The lower clamp encloses a portion of the gastric lumen suitable in size for the anastomosis, while the transected stomach held in the upper clamp is closed in two layers.

Provided that the greater curve has been adequately mobilised, the gastric remnant can be brought to the duodenum and anastomosed without tension. Stay sutures are inserted into the tissues that are to be approximated. Either a single- or a two-layer anastomotic technique is suitable. When a two-layer technique is used, the outer layer usually consists of interrupted seromuscular sutures, and this posterior outer layer is placed first. The posterior wall is then completed by an all-layer continuous suture. This suture is continued forwards as the all-layer suture of the anterior aspect of the anastomosis, before the final anterior interrupted seromuscular sutures are placed. In a one-layer technique, only the continuous all-layer suture is employed, and the outer interrupted seromuscular sutures are omitted. Particular care must be taken with suture placement at the ‘angle of sorrow’, the ‘lesser curve’ of the anastomosis (i.e. the junction between the part of the stomach that has been closed and the part used for the anastomosis), as this is the area that is especially prone to leakage.

Alternatively, the anastomosis may be performed using an end-to-end anastomotic circular stapler (Figure 8.29d). The stapler head is inserted into the duodenum and secured using a purse-string suture.



8.29 Billroth I gastrectomy. (a) The greater curve has been mobilised inside the gastroepiploic arcade and the lesser curve outside the gastric arcade. The duodenum is divided with a stapling device or between clamps. (b) The stomach is divided with a linear cutting stapling device. (c) A wedge at the greater curve is excised for the anastomosis. (d) A stapled alternative to the traditional hand-sewn Billroth I anastomosis. ⏎

The stapler is inserted into the stomach through a small incision at a more proximal site. The spike of the locking device is brought out distally, avoiding the staple or suture line of the distal stomach. The two portions of the stapling device are locked into place, approximated and the staples fired. The gastrotomy used to introduce the circular stapler is then closed by elevating it between Babcock forceps and firing a linear stapler. Alternatively, the defect can be sutured. To confirm duodenal integrity, some saline is instilled around the anastomotic site, a non-crushing clamp is placed distal to the duodenum and the duodenum inflated with air via the nasogastric tube. An absence of bubbles helps to confirm integrity.

Billroth II gastrectomy

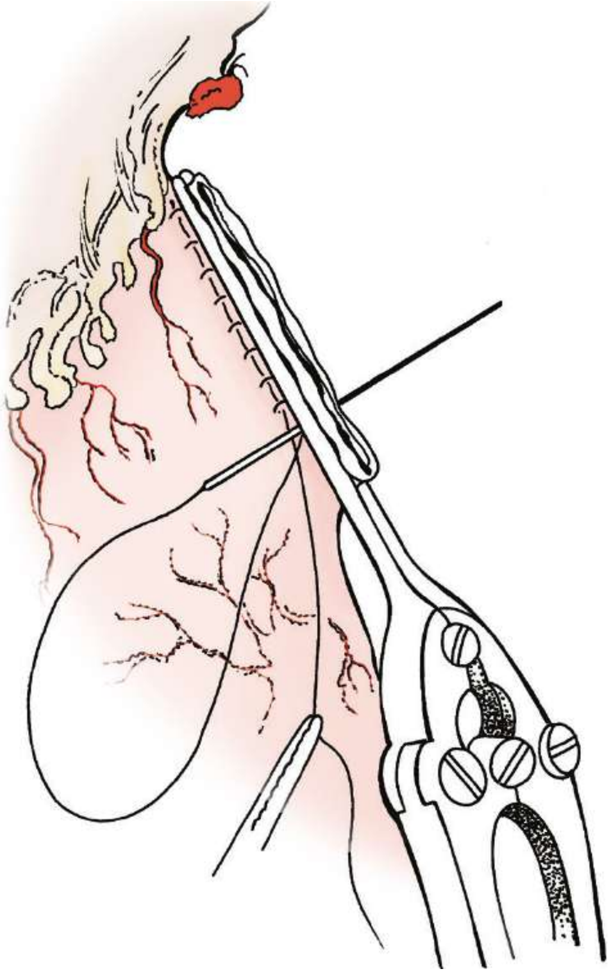
Many different types and variations of this gastrectomy have been described, but a Billroth II gastrectomy essentially involves a distal gastric resection, with closure of the duodenal stump, and restoration of intestinal continuity by a gastrojejunostomy. The technique was first described in 1911. Since then, surgeons have opted for longer loops of jejunum, with some favouring an antecolic anastomosis and others a retrocolic anastomosis. While the Billroth II reconstruction is associated with a higher incidence of reflux gastritis and dumping syndrome than Billroth I, it offers an alternative in any situation where a Billroth I is not technically possible owing to excess tension at the anastomotic site.

Operative procedure The initial steps for a Billroth II gastrectomy are similar to those described for a Billroth I gastrectomy. However, a smaller gastric remnant is often left, as it need not reach the duodenum for reconstruction. At this stage, the zone of demarcation between ischaemic and well-perfused stomach acts as a guide when deciding on the level for the gastric transection. The duodenum is then Kocherised. Occasionally, the duodenum may be adherent to the pancreas secondary to an ulcer and must be dissected off the pancreas carefully under direct vision. Once the inferior portion of the first part of the duodenum is freed, a linear stapling device is passed posterior to the duodenum and the duodenum transected. The rows of staples on the duodenal stump may then be reinforced by a continuous absorbable seromuscular suture (e.g. 3/0 PDS®), which buries the suture line. The old 'sewing machine' stitch for the first layer may be useful when the duodenal stump is short and difficult to invaginate (Figure 8.30).

The next stage depends on whether stapling devices are to be used for the transection and for the anastomosis. The proximal loop of jejunum is then brought up through the transverse mesocolon, and a gastrojejunostomy can be fashioned using an intestinal stapling device. Alternatively, a portion of the staple line at the greater curve can be trimmed and a hand-sewn anastomosis constructed.

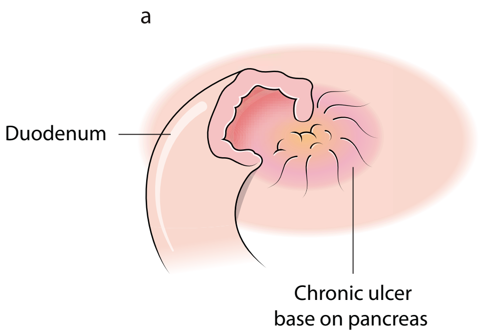
The Roux-en-Y gastrojejunostomy is an alternative technique to restore gastrointestinal continuity.

Difficult duodenal stump closure Occasionally, when there is a very large duodenal ulcer, it may not be possible to staple or suture close the duodenal stump. Giant peptic ulcers of the stomach or duodenum (>2.5 cm) that penetrate the pancreas or liver or fistulate into the transverse colon or other adjacent viscera may occur. A giant posterior penetrating duodenal ulcer usually precludes closure of the duodenal stump, and overenthusiastic attempts may result in injury to the common bile duct. The Nissen's technique may be a safer way to deal with this situation (Figure 8.31).

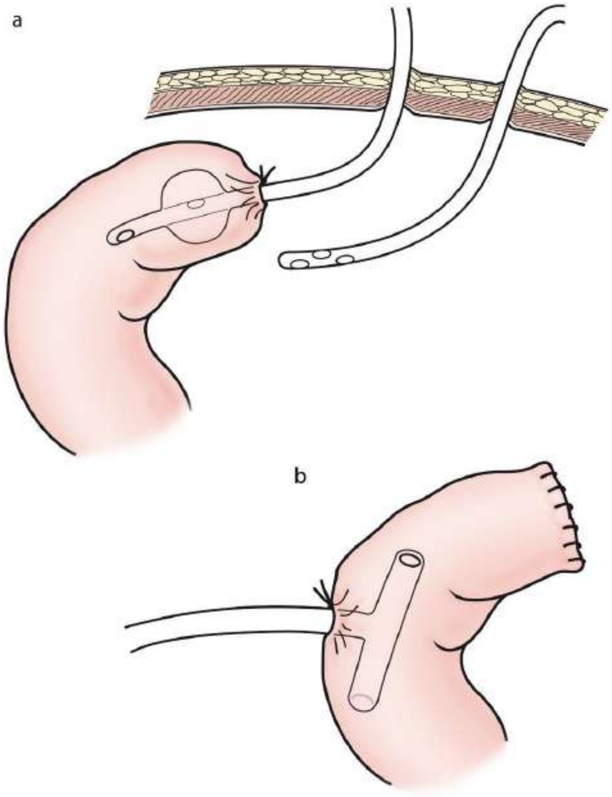


8.30 The 'sewing machine' stitch can still be a useful suture for closure of a difficult duodenal stump when no stapling devices are available. ⏎

If closure involves any excess tension on the stump or the tissue is unable to hold sutures adequately, then it may be better to create a controlled duodenal fistula. This is done by inserting a Foley catheter into the stump and anchoring it with a purse-string suture (Figure 8.32a). The area is then buttressed using greater omentum. Alternatively, a lateral duodenostomy tube can be inserted (Figure 8.32b) or even a large-bore tube simply secured in the vicinity of the open duodenal stump. Once the catheter or T-tube has been removed, the duodenal fistula should close spontaneously if there is no afferent limb obstruction.



8.31 Nissen's technique. ⏎



8.32 Solutions for the difficult duodenal stump. A controlled fistula onto the skin surface can be created with (a) a Foley catheter inserted into the duodenum or even with a drain left adjacent to an open duodenal stump or (b) a lateral duodenostomy using a T-tube. ⏎

Laparoscopic gastrectomy for benign disease

The dissection for an N0 gastrectomy is eminently suitable for a laparoscopic operation. The position of port sites varies according to surgeon preference and patient body habitus but a 10 mm umbilical camera port and a 12 mm right hypochondrial port, in addition to a further 5 mm right hypochondrial port and two left hypochondrial ports, is a satisfactory arrangement. A steep head-up tilt improves access. The harmonic scalpel or LigaSure energy devices can be used for division of the gastric branches of the gastroepiploic vessel and division of the lesser omentum. The duodenum and stomach are divided with an endoscopic stapling device, but serial firing is necessary for the gastric transection. A Billroth II reconstruction is usually chosen for technical reasons. A window is formed in the transverse mesocolon to allow the loop of jejunum to be brought up for a retrocolic anastomosis, which is also performed with a stapling device in a similar fashion to that described for a laparoscopic gastroenterostomy above. After the anastomosis is performed, the stapler entry sites in the stomach and bowel wall may be closed with a single-layer 3/0 Vicryl intracorporeal continuous suture. Access seldom allows this to be closed with a stapling device. The specimen may be extracted through the umbilical port using a laparoscopic bag.

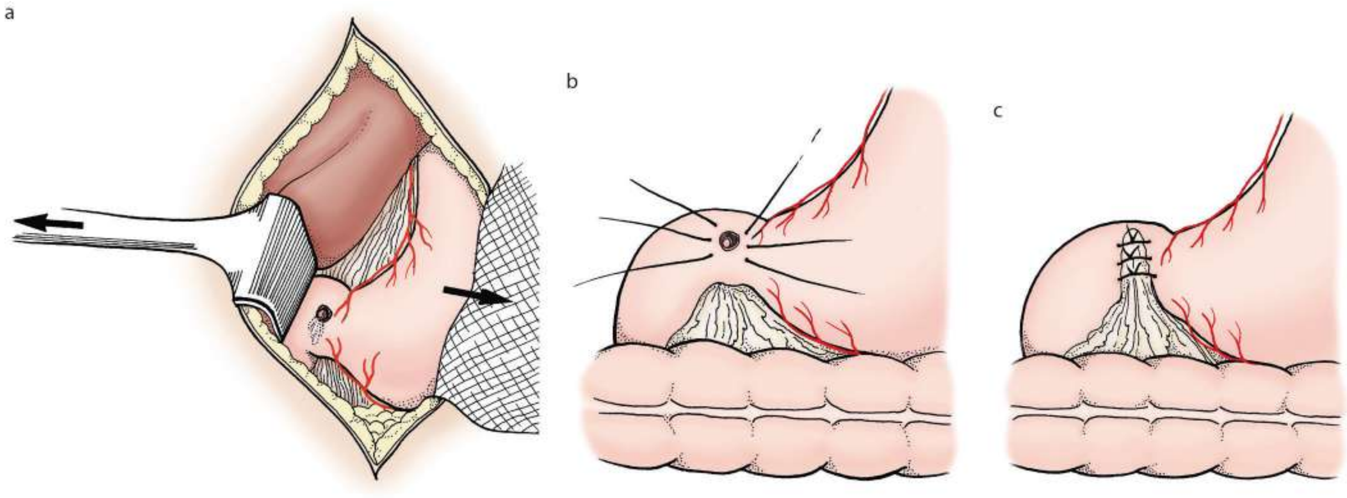
EMERGENCY SURGERY FOR PEPTIC ULCER

Most operations nowadays for peptic ulcer are performed for acute complications. The three most common complications of peptic ulcer disease requiring surgical intervention are perforation, bleeding and stenosis (causing gastric outlet obstruction).

Perforated peptic ulcer

The classical presentation of a perforated peptic ulcer involves sudden onset of epigastric pain. An erect chest X-ray will reveal free air in approximately 65% of cases. Often, although a perforated ulcer is suspected, only a preoperative diagnosis of a perforated viscus or generalised peritonitis is possible. After resuscitation and elimination of non-surgical pathology, an emergency laparotomy, or laparoscopy, is planned. Turbid, bile-stained fluid confirms an upper, rather than a lower, gastrointestinal perforation.

Open surgery duodenal perforation operation In most cases, the perforation is easily recognised. The



8.33 Perforated duodenal ulcer. (a) Good retraction facilitates access to the duodenum and the identification of the perforation site. (b) Sutures in place for a primary closure of the perforation. (c) This can be reinforced with an omental patch using the same sutures. ⏎

anterior aspect of the first part of the duodenum and distal stomach are inspected first. A retractor is carefully inserted under the liver and the stomach is drawn down, grasping it with a moist pack (Figure 8.33a). Overlying omentum is peeled away. If no perforation becomes apparent, the remainder of the anterior aspect of the stomach and duodenum is inspected. On rare occasions, a posterior ulcer has perforated into the lesser sac.

A perforated duodenal ulcer is most appropriately managed by simple closure with three or four interrupted, absorbable sutures. Generous bites, which pass through the entire thickness of the gut wall, should be taken. Care must be taken to ensure that they do not catch the posterior wall. Sutures should be inserted in the long axis of the gut to avoid narrowing (Figure 8.33b). The closure should then usually be reinforced with an omental on-lay patch, a 'modified Graham patch' (Figure 8.33c). If the ulcer is large and inflamed, the sutures tend to 'cheese-wire' through the tissues and it is better not to attempt to draw the edges together. Instead, the defect is closed using an omental patch alone: a 'true Graham patch'.

Occasionally, the entire duodenal wall is eroded and it may be necessary to proceed to a Billroth II gastrectomy. In these circumstances, closure of the duodenal stump is unlikely to be possible and a controlled duodenal fistula may be created by tube drainage (see Figure 8.32).

Does one need to consider definitive antisecretory procedures along with pedicled omental patch closure?

- In the setting of shock, delayed presentation, considerable comorbid disease and marked peritoneal contamination, simple patch closure is all that is needed.
- Simple patch closure is also adequate in the setting of acute NSAID-induced perforation or *Helicobacter pylori*-associated perforation and for patients who have never been treated for peptic ulcer disease in the past.
- In the absence of the above-mentioned factors and in patients who have a previous history of ulcer surgery, or chronic symptoms despite medication, some patients may be candidates for a definitive anti-ulcer procedure.

However, the advances in the medical treatment of peptic ulcer disease together with the decrease in experience of elective anti-ulcer surgery have made definitive ulcer surgery in the emergency setting uncommon.

It is important to ensure thorough peritoneal cleansing after the closure of any gastrointestinal perforation in order to reduce wound infections and intra-abdominal abscess formation. Postoperatively, as soon as it is possible, patients should be commenced on triple therapy for *Helicobacter pylori* eradication. If the patient fails to settle postoperatively, the possibility of an intra-abdominal abscess must be considered. In most cases, when identified on ultrasound or CT scan, an abscess may be drained percutaneously under radiological guidance. The possibility that the patient has a persistent duodenal leak should be considered. This can be confirmed, or excluded, with a water-soluble contrast study.

Gastric perforation Perforated gastric ulcers may be malignant and should therefore be excised, or multiple biopsies taken, prior to primary closure of the perforation. The closure is again reinforced using an omental patch. Occasionally, if the ulcer is very large, a gastrectomy may be required. A perforated, overtly malignant gastric ulcer can pose difficult intraoperative decisions, especially if a gastrectomy cannot be performed through tumour-free planes. Any surgery, even for a small malignant ulcer that has perforated, is almost certainly palliative because of the contamination of the peritoneal cavity with malignant cells.

Laparoscopic repair of a perforated peptic ulcer

Laparoscopic treatment of perforated peptic ulcer disease was first published as early as 1990 and is becoming a more popular option. However, whereas an open repair is usually a simple procedure, a laparoscopic repair requires the surgeon to be proficient in intracorporeal knot tying. The fibrin seal between the undersurface of the liver, the gallbladder and the perforated ulcer is gently divided to expose the ulcer, with care being taken not to enlarge the existing perforation. The principles are then similar to those for an open technique. The laparoscopic approach allows better access, and vision, for peritoneal lavage, particularly in the subphrenic and pelvic spaces.

The patient is placed in a reverse Trendelenburg position, with the operator standing between the legs of the patient or at the patient's side. Generally, the first optical 10 mm trocar is placed at or just above the umbilicus using an open technique. Once the pneumoperitoneum has been insufflated, the whole abdominal cavity is explored using a 30° optical telescope. The other trocars (usually three) are positioned under visual control. One 5 mm trocar is placed under the xiphisternum for liver retraction. The other two trocars are positioned in the left abdominal quadrant on the mid-clavicular line, above the umbilical transverse line (5 mm), and on the right side (5 mm). Usually, it is easy to identify an anterior duodenal perforation but if the perforation is located in a 'difficult' site (lateral wall of the descending duodenum, posterior gastric wall) some additional manoeuvres need to be performed, such as mobilisation of the duodenum or a section of the gastrocolic ligament to access the cavity behind the greater omentum. If the site of perforation cannot be identified despite these manoeuvres, conversion to an open operation may be necessary. Conversion should not be considered a failure, as the detection, and safe closure, of the perforation takes precedence over the choice of surgical access.

Shock, delayed presentation, confounding medical conditions, age greater than 70 years, poor laparoscopic expertise and higher American Society of Anesthesiologists (ASA) grade are associated with worse outcomes, even with laparoscopic surgery.

Conservative management of a perforated peptic ulcer This is more appropriate for duodenal than for gastric perforations and may be considered for patients with a delayed presentation (i.e. greater than 24 hours) and extensive comorbid factors. In patients who are haemodynamically stable with minimal abdominal symptoms, the ulcer may already be sealed by the greater omentum or adjacent organs. A non-operative approach involving adequate rehydration, nasogastric tube aspiration, broad-spectrum antibiotics, thromboembolic prophylaxis and acid suppression has been shown to be effective in a selected group of patients. Patients are monitored closely, and any deterioration in clinical status will be an indication for consideration of operative intervention. The patient is susceptible to the development of subhepatic or subphrenic abscesses but, in the absence of generalised peritonitis, these can be managed by image-guided percutaneous drainage.

Peptic ulcer haemorrhage

Management of a bleeding peptic ulcer has been revolutionised by endoscopic technology and non-surgical expertise. The three cardinal principles in the management are:

1. Vigorous resuscitation of the patient after the initial bleed to restore haemodynamic stability, followed by monitoring for re-bleeding and appropriate resuscitation if this should occur
2. Prompt investigation to establish the cause
3. Institution of appropriate measures to arrest bleeding and prevent further haemorrhage

Despite the rapid endoscopic advances, the mortality from bleeding ulcers remains at 5–10% (Contini and Scarpignato, 2013).

The various techniques of endoscopic haemostasis, if available, have dramatically reduced the need for emergency surgery for bleeding due to peptic ulceration. Injection therapies include injection of 1:10,000 adrenaline, fibrin glue and thrombin. Thermal haemostatic techniques include heater probe, multipolar coagulation (BICAP) and argon plasma coagulation. Mechanical endoscopic clips are useful to control bleeding from a large artery. Endoscopic treatment by a combination of two different modalities has a better success rate.

An estimated 10–20% of patients with bleeding ulcers fail endoscopic therapy and may require surgical intervention. Although repeat endoscopic intervention may be successful, mortality from salvage surgery, if it becomes necessary, increases with delay to intervention. The old lessons on the dangers of procrastination must not be forgotten. A large vessel, visible in the ulcer base, a major initial bleed, a re-bleed in hospital and advanced age are all factors that should encourage surgical intervention. If facilities exist, radiological embolisation is an alternative strategy for patients in whom endoscopic treatment has failed.

Operative procedure for a bleeding duodenal ulcer Upper gastrointestinal endoscopy is imperative prior to operative intervention to identify the site of haemorrhage, as this will direct surgical access towards the bleeding site. Very occasionally, the bleeding is so torrential that the patient must be taken directly to the operating theatre. In this situation, endoscopy can be performed in theatre after induction, but this may be unhelpful if major haemorrhage is obscuring the view. A midline laparotomy, with division of the falciform ligament to allow upwards retraction of the liver, should give good access.

If the bleeding is from a duodenal ulcer, two stay sutures are inserted on either side of the pylorus, using the prepyloric vein of Mayo as a guide. A longitudinal pyloroduodenotomy is made, and direct finger pressure on the bleeding site will control the haemorrhage, allowing the anaesthetist to resuscitate and stabilise the patient. If the bleeding site is not obvious, then careful inspection, and palpation, may identify an area of induration, which represents a thrombosed vessel. Careful lavage and gentle suction will help to dislodge clots that overlie the bleeding vessel. With a bleeding gastroduodenal artery, sutures should be inserted to gain control. Sutures are placed proximally and distally on the gastroduodenal artery, and a third suture is inserted to control its transverse pancreatic branch, which may be a cause of re-bleeding if not ligated (Figure 8.34). (This risk of further bleeding has led some surgeons to recommend a gastrectomy as the alternative surgical option.) Placement of sutures too deeply in the tissues should be avoided due to the risk of incorporating the pancreatic or common bile duct. Interrupted sutures are then used to close the pyloroduodenotomy incision transversely, to prevent narrowing of the pyloric channel. As discussed above, there is seldom any justification for adding a definitive antisecretory procedure.

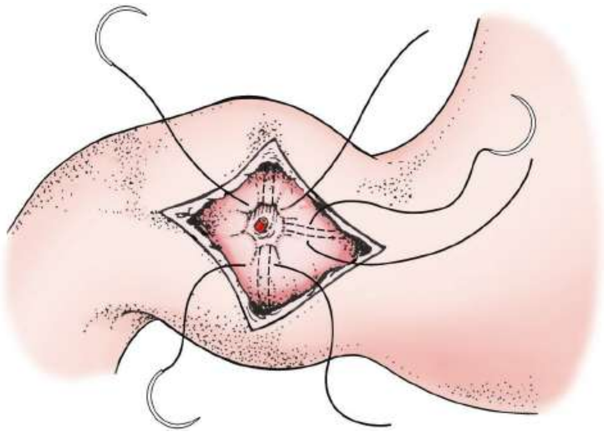
Operative procedure for a bleeding gastric ulcer Ideally, the precise site of the bleeding has been identified by preoperative gastroscopy, and an ulcer can be located by palpation of the relevant area of the stomach. When a posterior ulcer is suspected, the lesser sac will have to be entered to examine the posterior aspect of the stomach. An antral or pyloric ulcer may be detected by digital palpation of the mucosa through a pyloroduodenotomy, if this has already been performed. If no bleeding site can be identified, it may be necessary to make a second gastrotomy. Intraoperative endoscopy can also be helpful in identifying the bleeding point and directing the placement of gastric incisions.

Once the bleeding point in the stomach has been identified, the surgeon must decide on the most appropriate strategy. Under-running suturing of the bleeding vessel from within should secure haemostasis, and this is often recommended for the small Dieulafoy lesion. In contrast, a very large ulcer eroding into a major branch of the left gastric artery may necessitate a subtotal gastrectomy incorporating the ulcer.

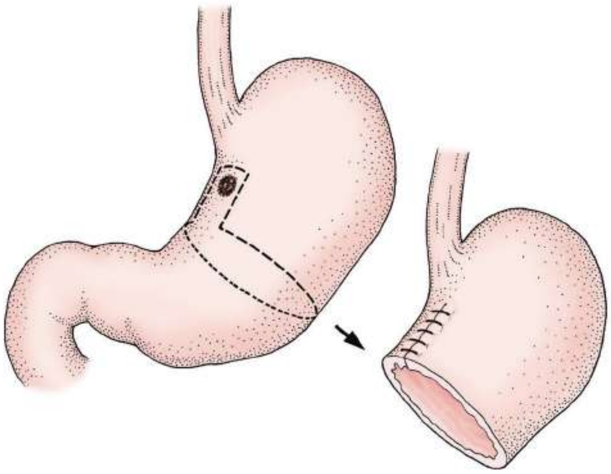
An ulcer high on the lesser curve, which is eroding the left gastric artery, may not be included in a standard partial gastrectomy. It can be incorporated into the resection by a Pauchet manoeuvre, in which the ulcer is excised with a tongue of gastric wall. A new 'lesser curve' is created by apposing the cut anterior and posterior gastric walls with a continuous absorbable suture (Figure 8.35).

Gastric outlet obstruction

Gastric outlet obstruction can result from peptic ulcer disease of the duodenum or the prepyloric region. Patients typically present with symptoms of gastric distension, bloating, indigestion, satiety, vomiting



8.34 Suture ligation of a bleeding gastroduodenal artery. The sutures must incorporate the artery proximal and distal to the site of the bleeding ulcer and must also control its transverse pancreatic branch. ⏎



8.35 Pauchet manoeuvre. ⏎

and weight loss. They are also malnourished and dehydrated and present with metabolic alkalosis. Correction of dehydration and electrolyte imbalance is essential before attempting surgical correction.

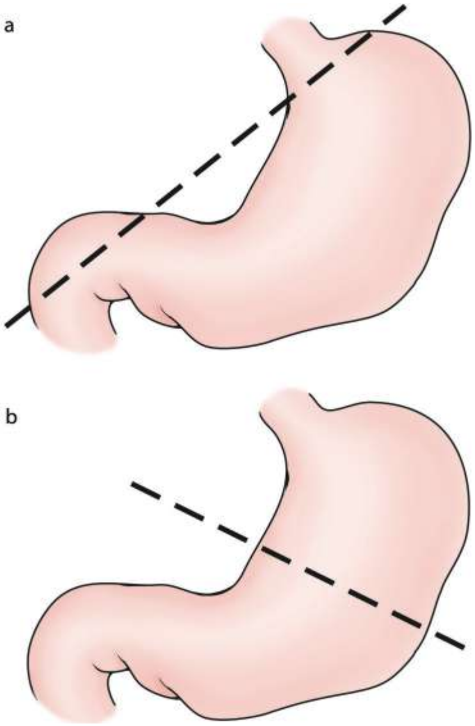
The operation with the fewest complications is a pyloroplasty (or gastroenterostomy when the inflammation around the pylorus is particularly intense), with the use of long-term medical acid suppression. Antrectomy and selective vagotomy or subtotal gastrectomy are more aggressive alternatives that are less likely to result in re-stenosis, but with a higher mortality and incidence of both short- and long-term side effects.

Laparoscopic truncal vagotomy and gastroenterostomy has proven to be a technically feasible solution with a good symptomatic, sustained response.

GASTRIC VOLVULUS

A gastric volvulus occurs when the stomach rotates on itself by at least 180° along its transverse or longitudinal axis. Gastric strangulation is a complication that can occur after the development of acute gastric volvulus. In 10–30% of cases, gastric volvulus is considered primary, resulting from laxity and disruption of the stomach's ligamentous attachments (gastrohepatic, gastrocolic, gastrosplenic, and gastrophrenic). However, in the majority, a gastric volvulus is associated with underlying pathology such as a para-oesophageal or diaphragmatic hernia. Patients may present with chronic non-specific symptoms including vomiting and postprandial epigastric pain. A proportion of patients will present with severe pain and retching, without the ability to vomit. The inability to pass a nasogastric tube beyond the distal oesophagus completes *Borchardt's triad*. Gastric volvulus is a closed-loop obstruction that causes progressive gastric distension and represents a surgical emergency, as the blood supply to the stomach may be rapidly compromised. There are two types of gastric volvulus defined by their axis of rotation: organo-axial and mesentero-axial. An *organo-axial* volvulus occurs around a line between the pylorus and the OG junction and is more common in older people (Figure 8.36a). A *mesentero-axial* rotation occurs in a plane running from the porta hepatis to the greater curve of the stomach and has a higher incidence in children (Figure 8.36b). Very rarely, a combined form is encountered.

Plain chest X-ray films may show a spherical stomach or a double air–fluid level on an upright chest film and the retrocardiac air–fluid level above the diaphragm on a lateral chest film. An upper gastrointestinal contrast study may show a reversal of the relative position of the greater curvature of the stomach and a downward-pointing pylorus. A CT scan may provide information about the nature of the volvulus and other intra-abdominal organs that may be involved, thus assisting preoperative planning.



8.36 Gastric volvulus. (a) Organo-axial rotation on an axis between the pylorus and the OG junction. (b) Mesentero-axial rotation occurring on an axis from the porta hepatis to the greater curvature of the stomach. ⏎

When a patient presents acutely with suspected gastric volvulus, an attempt should be made to pass a nasogastric tube. If nasogastric deflation fails, endoscopic decompression may be successful but carries a risk of gastric perforation. If decompression is not achieved, emergency surgery is essential to reduce the volvulus. If the stomach is viable and there is no evidence of coexisting pathology, a simple gastropexy in which the anterior stomach wall is sutured to the anterior abdominal wall should suffice. If there are adhesive bands, these are divided and any associated diaphragmatic defect is repaired. In the presence of gastric necrosis, or perforation, a subtotal or total gastrectomy may be necessary.

There are several other methods of fixing the stomach to prevent recurrent volvulus. It can be fixed to the anterior abdominal wall by a gastrostomy or its mobility can be restricted by a gastrojejunostomy. A percutaneous endoscopic gastrostomy (PEG) tube is another method of fixation and may be the most suitable for high-risk patients.

BARIATRIC SURGERY

The indications for bariatric surgery include a body mass index (BMI) of ≥40 kg/m^2 or a BMI of ≥35 kg/m^2 with an obesity-related comorbidity. Asian guidelines have a lower BMI cut-off: ≥37.5 kg/m^2 or ≥32.5 kg/m^2 in the presence of comorbidities. Within these groups, bariatric surgery is best suited to well-motivated patients with acceptable operative risks and who strongly desire substantial weight loss.

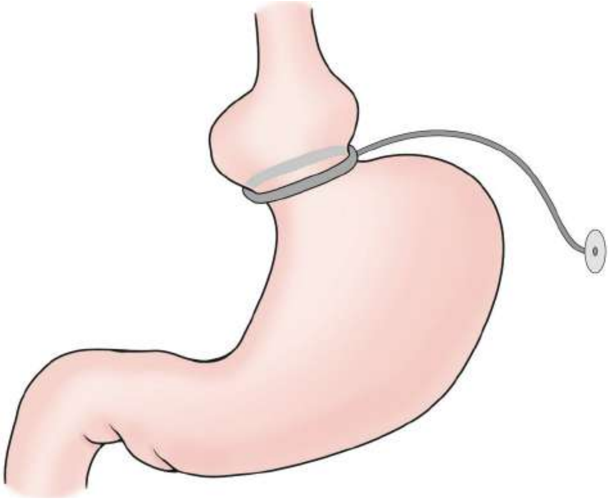
Bariatric surgical procedures affect weight loss through three fundamental mechanisms: restriction, malabsorption and the neurohormonal response that regulates hunger and energy balance. Although bariatric procedures are classified based on the above-mentioned categorisation, most interventions work through a combination of these three factors. A multidisciplinary bariatric team providing advice on nutrition, lifestyle modification and motivation is essential for success with a surgical weight-loss programme.

The vertical banded gastroplasty and jejunoileal bypass were some of the first described bariatric procedures in the open era, but they are now obsolete and are therefore not discussed here. The most commonly performed operations include a laparoscopic adjustable gastric band, a laparoscopic sleeve gastrectomy (LSG) and a Roux-en-Y gastric bypass (RYGB). Less common procedures include the one-anastomosis gastric bypass (OAGB), the single-anastomosis duodenoileal bypass (SADI) and the biliopancreatic diversion (BPD) switch operations. The newer endoscopic procedures, such as the endoscopic sleeve gastroplasty and endoscopic barrier devices, are under evolution and still not standard practice.

LAPAROSCOPIC ADJUSTABLE GASTRIC BAND

Laparoscopic adjustable gastric banding is a purely restrictive procedure that compartmentalises the upper stomach by placing a tight, adjustable prosthetic band around the entrance to the stomach. The gastric band is a soft, locking, silicone ring that is connected to a reservoir port placed in the subcutaneous tissue. The port may be easily accessed by a syringe and needle. Injection of water into the reservoir leads to reduction in the band diameter, resulting in an increased degree of restriction. The band is easily removable and no anatomical changes are made that might interfere with future bariatric procedures.

Laparoscopic access is established in a similar manner to that described for other OG junction procedures. A calibration tube with an inflatable balloon can be a useful guide. The tube is inserted into the stomach, the balloon is filled with 15 mL of saline and the tube is then retracted until the balloon lies just below the OG junction. The gastrohepatic ligament is opened alongside the proximal lesser curve and the dissection continues behind the stomach towards the angle of His, creating a retrogastric tunnel. The gastric band is then introduced from the angle of His, brought through the perigastric opening and around the stomach. It is then locked in place around the distal end of the calibration tube beyond the balloon (Figure 8.37). The band can then be secured to the anterior wall of the stomach with interrupted sutures. The tubing between the band and the reservoir is brought out through a port site. The reservoir, or access port, is placed at a site that allows easy access for percutaneous volume adjustments. A small incision is made and the reservoir is placed directly on the rectus sheath, to which it is now sutured. The tightness of the band is adjusted according to the patient's weight loss, with larger volumes of saline resulting in a smaller stoma and more restriction of intake.

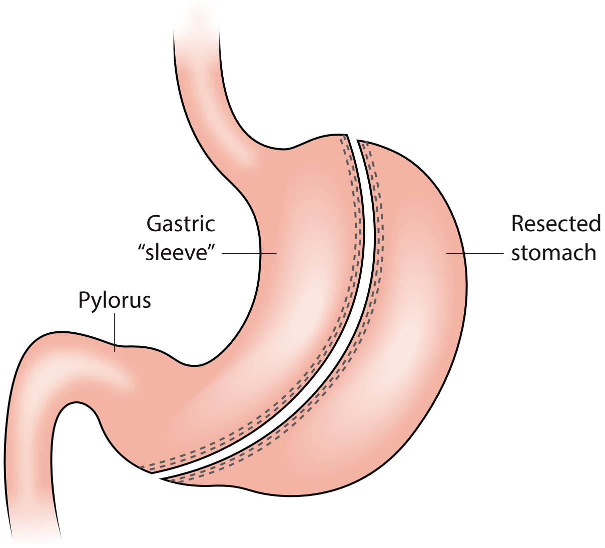


8.37 Laparoscopic adjustable gastric band. ⏎

Long-term complications include infection, band slippage and erosion of the band into the stomach. Band slippage may lead to potentially fatal gastric ischaemia. If a patient presents acutely with dysphagia, deflation of the band should be performed at presentation in the emergency department. If deflation does not relieve dysphagia or epigastric pain, further investigations should be performed and emergency removal considered.

LAPAROSCOPIC SLEEVE GASTRECTOMY

LSG is a partial gastrectomy in which the majority of the greater curvature of the stomach is removed, creating a tubular stomach (Figure 8.38). LSG was initially offered to patients with super severe obesity (BMI >60 kg/m^2) as the first stage in surgical management. However, this operation as a primary standalone procedure is currently the most commonly performed bariatric procedure across the world. This is because of the technical ease of LSG performance and the low risk of associated complications.



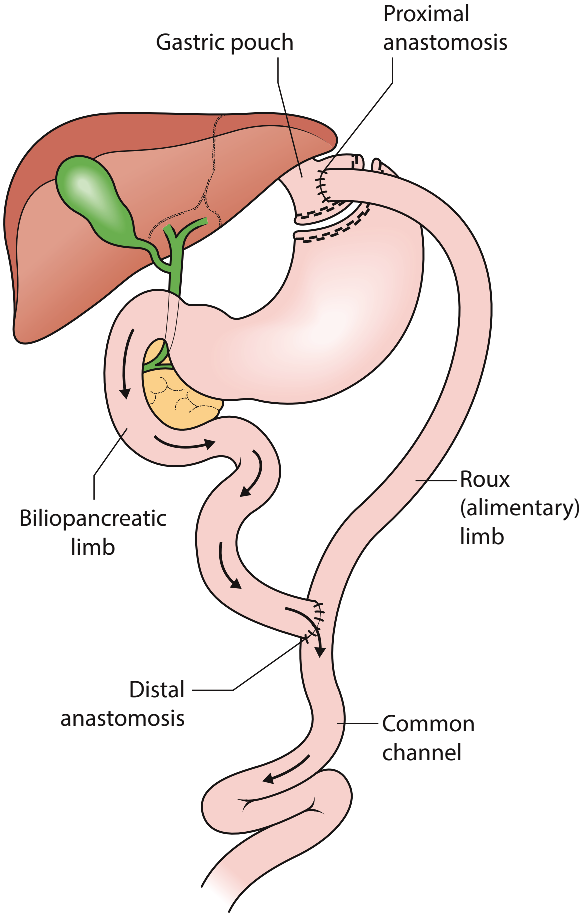
8.38 Laparoscopic sleeve gastrectomy. ⏎

The operation is performed laparoscopically and the port placement is similar to port positioning for a gastrectomy. The right subcostal port needs to be converted to a 15 mm port during stapling and for removal of the specimen. The greater curve is mobilised using a vessel-sealing device, staying close the stomach wall. The antrum is divided approximately 2 to 6 cm away from the pylorus, and a sleeve is created around a 40 French bougie by multiple firings of the laparoscopic linear stapler, starting in the gastric antrum (Figure 8.38). The resulting tubular stomach is small in its capacity (restriction) and is resistant to stretching due to the absence of the fundus. Although LSG is a restrictive procedure, gastric motility changes also occur with surgery, which help weight-loss outcomes. Moreover, the hormonal changes include a decrease in ghrelin levels and an increase in glucagon-like peptide-1 (GLP-1) and peptide YY (PYY) levels, resulting in less hunger, an improvement in insulin resistance and better glycaemic control. At 2 years, this procedure results in a reduction of approximately 60% of the excess body weight.

The LSG results in a high-pressure gastric pouch due to the presence of a sphincter at both ends. Therefore, LSG leaks are more difficult to manage and may even need revision to an RYGB to decrease the pressure in the pouch in order to help heal a leak from the gastric pouch. Additionally, LSG has a higher incidence of gastro-oesophageal reflux because of its higher pressure nature.

ROUX-EN-Y GASTRIC BYPASS

The RYGB remains one of the most commonly performed bariatric procedures and is considered the gold standard operation. However, as mentioned earlier, currently LSG has overtaken RYGB as the most performed bariatric operation.



8.39 Roux-en-Y gastric bypass. ⏎

The RYGB is performed laparoscopically by a creating a small (less than 30 mL) proximal gastric pouch that is divided and separated from the distal stomach. The small intestine is divided at a distance of 50 to 150 cm distal to the ligament of Treitz to create a proximal biliopancreatic limb that transports the secretions from the gastric remnant, liver and pancreas. The Roux limb (or alimentary limb) is anastomosed to the new gastric pouch and functions to drain the consumed food. The cut end of the biliopancreatic limb and the Roux limb are then anastomosed 75 to 150 cm distally from the gastrojejunostomy. The digestion and absorption of nutrients occurs in the common channel where the digestive enzymes and bile mix with the food (Figure 8.39).

The mechanism of weight loss after RYGB may be due to the following:

- RYGB has a combination of a restrictive component due to the formation of a small gastric pouch and a malabsorptive component due to the bypass.
- Gastrojejunostomy is associated with dumping and causes unpleasant symptoms of light-headedness, nausea, diaphoresis and/or abdominal pain, as well as diarrhoea when a high-sugar meal is ingested.

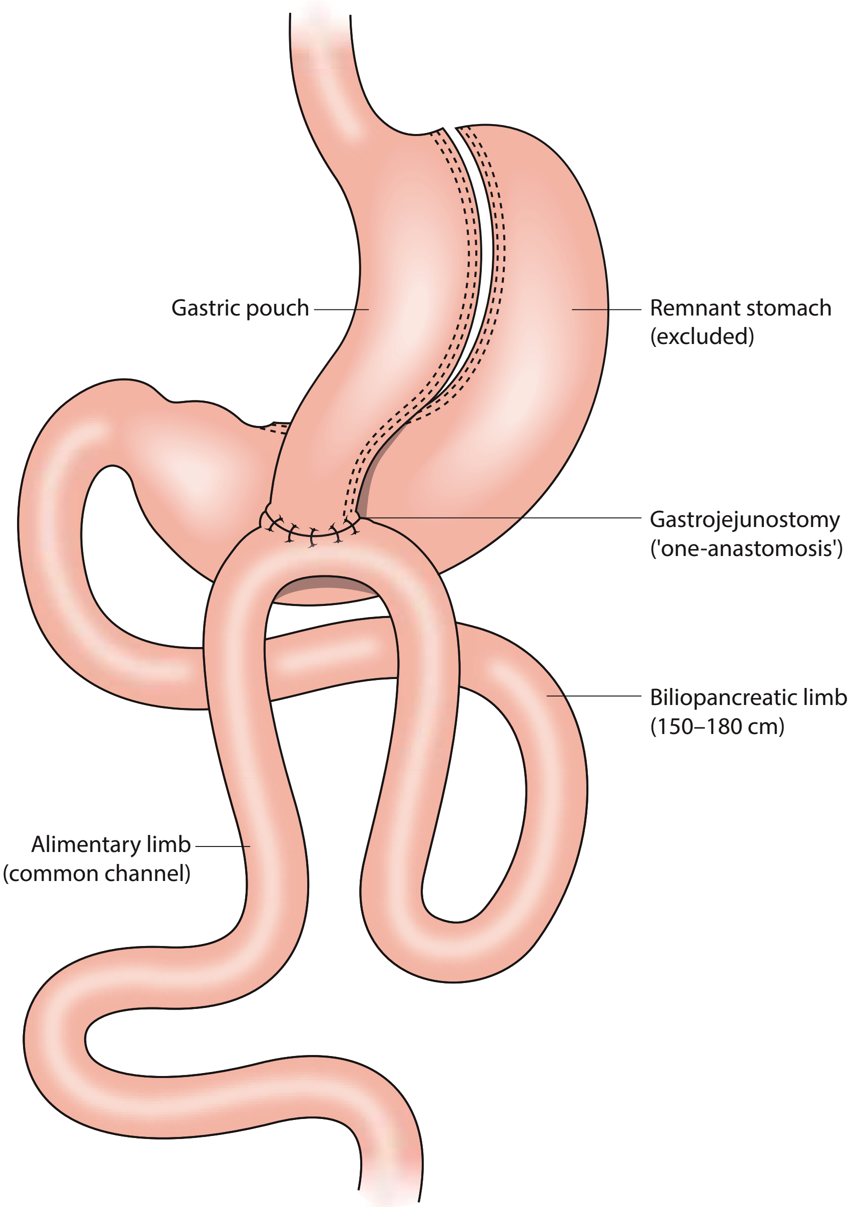
- The reduced ghrelin levels may contribute to the characteristic loss of appetite seen in post-RYGB patients. An exaggerated response of PYY may also contribute to the loss of appetite. Hormones such as GLP-1 and cholecystokinin (CCK), which are increased after RYGB, may promote an anorectic state with diminution in appetite.

Increasing Roux limb length can lead to increased malabsorption by effectively shortening the common channel limb where digestion and absorption of the ingested food occurs. However, current guidelines advise restriction of the Roux length to a maximum of 150 cm. If more weight loss is required, the length of the biliopancreatic limb may be increased, and this does not worsen the malabsorption-related complications.

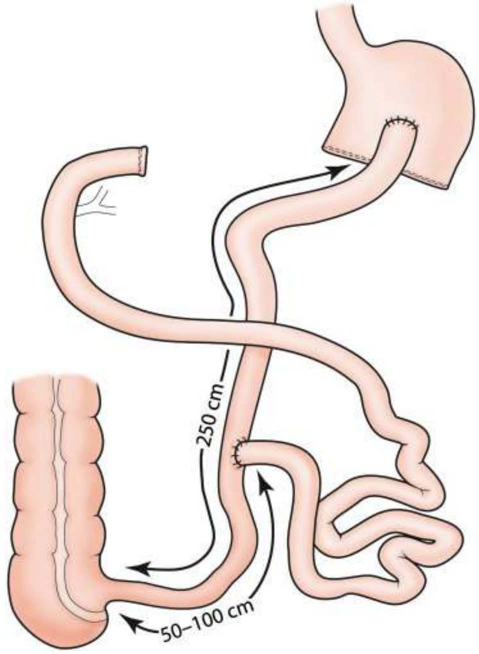
ONE-ANASTOMOSIS GASTRIC BYPASS

The OAGB is also termed as ‘mini-gastric bypass’ and is a modification of the RYGB, although it is technically simpler because it requires a single anastomosis. It was endorsed by the American Society for Metabolic and Bariatric Surgery (ASMBS) as a primary procedure in 2022. It is currently performed in many centres across the world.

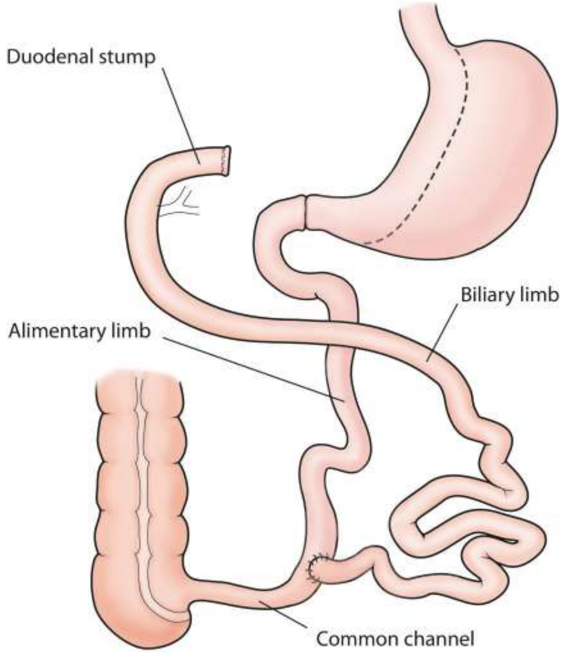
The OAGB is performed laparoscopically and includes the creation of a gastric pouch (Figure 8.40).


Gastric pouch
Remnant stomach (excluded)
Gastrojejunostomy ('one-anastomosis')
Biliopancreatic limb (150–180 cm)
Alimentary limb (common channel)

8.40 One-anastomosis gastric bypass (mini-gastric bypass). ⏎



8.41 Biliopancreatic diversion procedure. ⏎



8.42 Biliopancreatic diversion with a duodenal switch. ⏎

This gastric pouch is anastomosed to a loop of jejunum as an antecolic and antegastric loop gastrojejunostomy. Although there is no consensus on a standardised length, a biliopancreatic limb 150 cm distal to the ligament of Treitz is used to create the afferent limb.

BILIOPANCREATIC DIVERSION WITH DUODENAL SWITCH

The original BPD procedure involved performing a subtotal gastrectomy, leaving a 200–400 mL remnant. The jejunum was transected 250 cm from the ileocaecal valve. The distal ileal limb was then anastomosed to the stomach remnant and the proximal ileal limb to the distal ileum some 50–100 cm upstream of the ileocaecal valve (Figure 8.41).

A BPD is now commonly combined with a duodenal switch (DS) operation, and this combination has in general replaced the BPD from which it was developed. The BPD/DS procedure involves creating a sleeve gastrectomy with preservation of the pylorus and creation of a Roux limb with a short common channel (Figure 8.42). The BPD/DS procedure differs from the BPD in the portion of the stomach that is removed, as well as in the preservation of the pylorus, similar to an LSG. This allows more forwards flow of the contents of the biliopancreatic limb and avoids the complications of stasis that plagued the jejunoileal bypass. It is associated with a lower incidence of stomal ulceration and diarrhoea than a BPD alone. However, sleeve gastrectomy complications can still occur with this procedure.

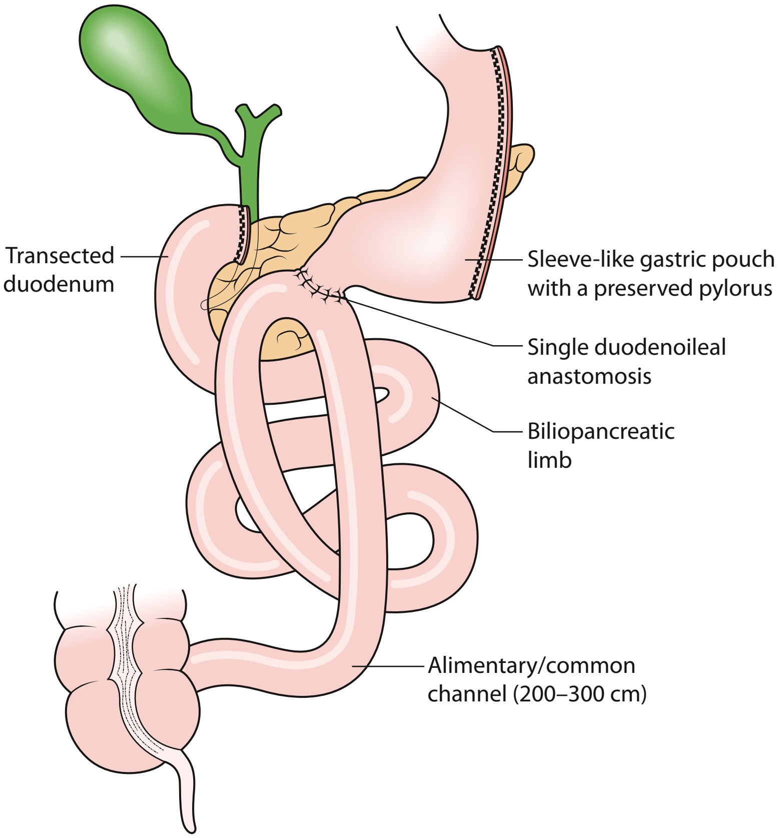
SINGLE-ANASTOMOSIS DUODENOILEAL BYPASS WITH SLEEVE GASTRECTOMY

SADI with sleeve gastrectomy (SADI-S) is a variant of the BPD/DS operation wherein the transected duodenum is anastomosed to a loop of distal small bowel as opposed to the Roux-en-Y configuration used in the classic BPD/DS. The SADI-S procedure was developed to reduce the complexity and therefore the risks of performing a Roux-en-Y configuration and to avoid the need for two anastomoses (Figure 8.43). SADI-S has been endorsed by the ASMBS as an appropriate primary or revisional metabolic bariatric procedure.

REVISIONAL PROCEDURES

BAND REVISIONS

For patients who fail to lose weight with a gastric band or who have complications from the band requiring removal, there are various options. Most would advocate a staged approach, wherein the band is first removed and, after a period of 8 to 12 weeks, the revision procedure performed. The band can be replaced or it can be converted to a sleeve gastrectomy, an RYGB or a BPD/DS.


Transected duodenum
Sleeve-like gastric pouch with a preserved pylorus
Single duodenoileal anastomosis
Biliopancreatic limb
Alimentary/common channel (200–300 cm)

8.43 Single-anastomosis duodenoileal bypass with sleeve gastrectomy. ⏎

SLEEVE REVISIONS

One criticism of the sleeve gastrectomy was the lack of durability of the operation, as the remnant stomach pouch could expand with loss of restriction. However, most series show that it is quite a durable procedure. The sleeve has the advantage that it can be converted into an RYGB, an OAGB, a BPD-DS or a SADI-S procedure as revisional procedures.

RYGB REVISIONS

Enlargement of the gastric pouch, fistula formation between the gastric pouch and the remnant stomach, or enlargement of the anastomosis between the gastric pouch and the Roux limb may result in failure of the procedure. These conditions may be an indication to surgically revise the gastric pouch or the gastrojejunal anastomosis.

Some patients may have no issues with the gastric pouch, but regain weight or may have issues with comorbidity control. Revision of the jejunojejunostomy anastomosis to make the biliopancreatic limb longer ('distalisation'), without sacrificing too much of the common channel, may be performed.

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9

Operative management of upper gastrointestinal malignancy

Saqib A Rahman and Philip H Pucher

ANATOMY

OESOPHAGUS

The oesophagus is an epithelial lined muscular tube that lies mainly in the superior and posterior mediastina. It commences in the neck as a continuation of the pharynx, with its upper end encircled by the cricopharyngeal sphincter. The bodies of the cervical vertebrae lie posterior to the oesophagus and the trachea lies immediately anteriorly. The recurrent laryngeal nerves lie in the groove between the oesophagus and the trachea. Anteriorly in its intrathoracic course, the oesophagus is related first to the trachea, followed by the right pulmonary artery and then the pericardium. Throughout its course, it lies on the bodies of the thoracic vertebrae. It passes through the diaphragm in a hiatal sling formed mainly by the fibres of the right crus. Its final 2 cm is as an intraperitoneal organ before it terminates at the *cardia*, or gastro-oesophageal junction (GOJ). Oesophagogastric reflux is prevented by a functional lower oesophageal sphincter, which is dependent more on the distal portion of the oesophagus lying intra-abdominally and the angle at which it enters the stomach than on any anatomical sphincter at the cardia. The vagus nerves form a plexus on either side of the oesophagus, but at the level of the hiatus the left vagus lies anteriorly and the right vagus posteriorly. The epithelial lining is squamous, except for the distal 2 cm where there is a variable transition zone to gastric mucosa.

Arterial supply

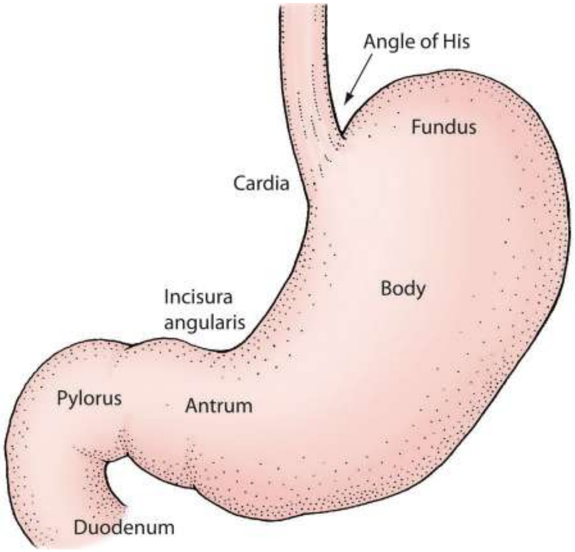
The arterial supply to the oesophagus is from the inferior thyroid artery from above and the left gastric and inferior phrenic arteries from below, and in its middle portion it is also supplied by bronchial arteries and small branches directly from the aorta. There is an extensive anastomosis between the arteries in the muscular and submucosal layers of the oesophageal wall. A *submucosal venous plexus* connects with that of the stomach and becomes varicose in portal hypertension, allowing portal venous blood to pass via the azygos vein to the superior vena cava.

Lymphatic drainage

There is an extensive lymphatic plexus in the submucosal layer of the oesophageal wall. This connects with another extensive para-oesophageal plexus, where lymph from the entire length of the oesophagus can mix before finally draining to cervical, thoracic and abdominal lymph nodes. Lymphatic drainage then follows the arterial supply.

STOMACH

The stomach is divided, mainly for descriptive purposes, into three major zones (Figure 9.1). The fundus lies above the GOJ. The angle of His is the acute angle between the fundus and the oesophagus. The



9.1 The stomach. ⏎

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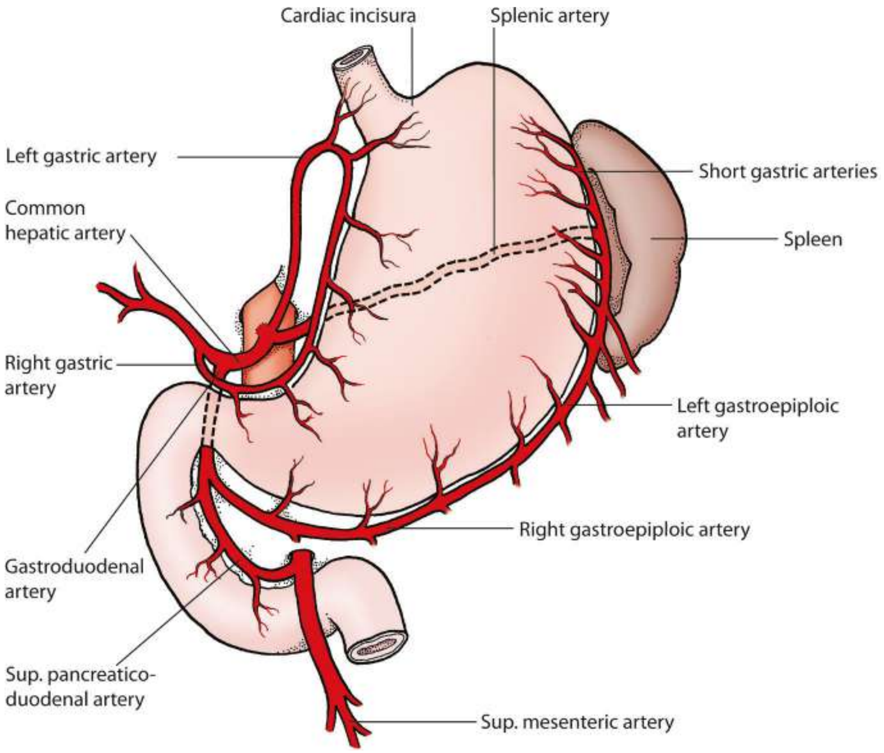
body is below the GOJ and is limited distally by the incisura angularis, a somewhat variable angulation of the lesser curve. The antrum is the portion of stomach distal to the incisura and extends to the pylorus. The pyloric sphincter is a condensation of the circular muscle of the stomach.

The stomach is completely invested in peritoneum, except for a small area posteriorly just below the cardia. The peritoneal coverings of the anterior and posterior walls of the stomach meet at the lesser curve and pass upwards as the lesser omentum, or gastrohepatic ligament, to the porta hepatis and a fissure on the posterior aspect of the liver. At the greater curve, the peritoneal layers meet to form the greater omentum and the gastrosplenic and gastrophrenic ligaments. These peritoneal folds around the stomach, and the subsequent division of the peritoneal cavity into a greater and lesser sac, are easier to understand from an embryological viewpoint. The mucosa of the body and fundus of the stomach contain *parietal cells*, which secrete acid, and *chief cells*, which secrete pepsinogen. The mucosa of the antrum contains gastrin-secreting *G cells*, which stimulate the parietal cells to secrete acid.

Arterial supply

The arterial supply to the stomach is almost exclusively from the coeliac axis, which arises from the aorta behind the lesser sac. The branches to the stomach enter the extremities of the lesser and greater omenta to form two arterial arcades, which lie between the peritoneal folds, 1–2 cm from the stomach wall. Multiple branches from these arcades pass to the lesser and greater curve (Figure 9.2). The gastric arcade, within the lesser omentum, is formed by the descending branch of the left gastric artery and the right gastric branch of the common hepatic artery. The gastroepiploic arcade, within the greater omentum, is formed by the right gastroepiploic branch of the gastroduodenal artery and the left gastroepiploic branch of the splenic artery. In addition, the upper part of the greater curve receives some four or five short gastric arteries from the splenic artery or one of its terminal branches. It is this rich anastomotic blood supply from several arteries converging from different directions that makes much of gastric surgery possible. There are also collateral anastomoses, both with branches of the superior mesenteric artery supplying the duodenum and with the aortic branches supplying the oesophagus. For this reason, gastric ischaemia, in occlusive vascular disease, is very uncommon, even when the coeliac axis is completely occluded. The venous drainage of the stomach is into the portal system, except for the alternative systemic route via the submucosal venous plexus, across the GOJ and into the azygos vein.



9.2 Arterial supply to the stomach and proximal duodenum. ⏎

Lymphatic drainage

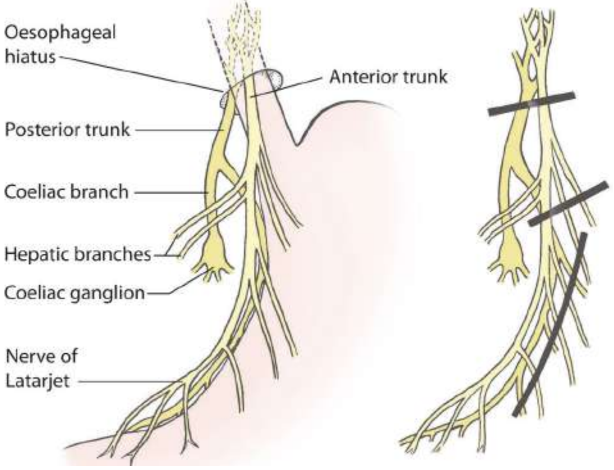
The lymphatic drainage of the stomach follows its arterial supply, in a similar fashion to the pattern encountered throughout the gastrointestinal tract. The main lymphatic channels are therefore initially along the gastric and gastroepiploic arterial arcades, and the perigastric lymph nodes lie alongside the vessels. The lymphatics then accompany the main arteries supplying the stomach to their origin from the aorta. Further nodes lie alongside the retroperitoneal routes of these arteries, and the lymph finally drains into the preaortic nodes. There are anastomotic lymphatic channels that have a similar function to arterial collaterals and become of greater importance when the main channels are blocked by a tumour. Knowledge of the lymphatic drainage of the stomach has important implications for the staging and treatment of gastric cancer.[1] The associated lymph nodes have been named and numbered. They have also been divided into 'tiers' of lymph nodes to which gastric cancer may spread in a progressive fashion. As a simplification this can be viewed as:

- *First tier (N1)* – perigastric nodes closest to the tumour
- *Second tier (N2)* – further, more distant perigastric nodes and nodes along the course of the main artery that supplies the area of stomach from which the tumour has arisen
- *Third tier (N3)* – nodes outside these main pathways

Resections can now be planned to excise all N1 nodes, to excise all N1 and N2 nodes or even to include some N3 nodes. However, this is complicated by the different lymphatic drainage in different areas of the stomach, and an N1 node for a pyloric cancer will be an N2 node for a cancer at the cardia. Gastric lymphadenectomy is discussed in more detail in the sections on gastric cancer later in this chapter.

Nerve supply

The stomach has both sympathetic and parasympathetic innervation, the latter being provided by the vagus nerves. Shortly after emerging from the oesophageal hiatus, the anterior vagus gives off hepatobiliary fibres and the posterior vagus a branch to the coeliac plexus. There are also branches to the cardia. The main trunks continue as the anterior and posterior nerves of Latarjet (Figure 9.3). The nerves of Latarjet supply multiple further branches to the body of the stomach, with each branch passing into the stomach wall close to a vascular pedicle. These fibres are motor to the upper stomach but, more importantly, stimulate the secretion of acid by the parietal cells. They are divided in the operation of highly selective vagotomy.



9.3 Vagal innervation of the stomach. The three bars indicate the level of transection in truncal vagotomy, selective vagotomy and highly selective vagotomy. ⏎

The nerves of Latarjet continue towards the antrum to end in a configuration known as the 'crow's foot', which innervates the myenteric plexus of the antrum. The terminal crow's foot is preserved in a highly selective vagotomy, as it is a motor nerve to the pylorus from the anterior vagus, on which effective gastric emptying depends.

OESOPHAGEAL MALIGNANCY

EPIDEMIOLOGY AND BACKGROUND

Oesophageal cancer represents a significant burden of disease worldwide, with both a high incidence and a high mortality. In 2020, there were approximately 600,000 cases of oesophageal cancer diagnosed worldwide, with 540,000 deaths.[1] Almost 80% of new cases were diagnosed in Asia, with proportionally fewer cases in Europe (8.8%) and North America (3.4%). There are, broadly, two subtypes of oesophageal cancer, squamous cell carcinoma (SCC) and adenocarcinoma, with SCC predominant worldwide.[2] In Europe and North America, adenocarcinoma has overtaken SCC in recent decades as more common, most likely related to the obesity epidemic and increasing gastro-oesophageal reflux disease (GORD), along with decreasing alcohol and tobacco consumption.

Oesophageal adenocarcinoma is often associated with Barrett's oesophagus, the metaplastic change of stratified squamous oesophageal mucosa to intestinal-type columnar in response to repeated acid exposure. The prevalence of Barrett's oesophagus is thought to be approximately 2%,[3] with 1–2% progressing to adenocarcinoma per year,[3,4] although there is considerable uncertainty in these estimates.

Adenocarcinoma therefore occurs most frequently in the distal oesophagus and GOJ, with proximal tumours rare. SCC can occur anywhere throughout the oropharynx or oesophagus where there is squamous mucosa, and is frequently associated with risk factor-associated field changes, with a corresponding risk of multiple tumours at distinct sites.

STAGING AND INITIAL WORKUP

Patients with oesophageal cancer most frequently present with dysphagic symptoms and undergo gastroscopy. After identification and biopsy of suspicious lesions, diagnosis is confirmed by histology, and patients are referred for staging investigations. In general, this consists of a contrast-enhanced computed tomography (CT) scan of the abdomen and thorax and in patients who are candidates for curative treatment, ^{18}F-fluoro-deoxyglucose positron emission tomography (PET-CT). PET-CT is useful in detecting occult metastases not demonstrated on staging CT and avoiding futile treatment in patients without a realistic chance of cure.

Endoscopic ultrasound (EUS) can be useful for quantifying the T stage of disease with a sensitivity of 81–92% and a specificity of 94–97%.[5] EUS is also frequently used for nodal staging, although its accuracy for this purpose is lower.[6] EUS is particularly useful in differentiating T4a (invading pericardium pleura, diaphragm) tumours, which are potentially resectable, from T4b tumours (invading trachea, vertebrae or aorta), which are not. Tracheo-bronchoscopy (with or without endobronchial ultrasound) may also be used selectively for this purpose. Early tumours potentially suitable for endoscopic resection (i.e. endoscopic mucosal resection or endoscopic submucosal dissection) may be staged with EUS; however, correlation of EUS staging with endoscopic pathology is not reliable. Staging laparoscopy should be conducted in patients with locally advanced tumours of the distal oesophagus/GOJ, as up to 10% of these patients may have occult peritoneal metastases that are not detectable by CT or PET-CT.[6] These patients do not benefit from radical therapy and should be considered for palliative oncological therapy instead.

In patients being considered for radical resection, an assessment of fitness for treatment at an early stage can help guide treatment decisions. Cardiopulmonary exercise testing (CPET) has rapidly expanded to fill this role and is routinely used for patient selection/prognostication in many centres. CPET assesses both cardiopulmonary status and overall fitness and involves increasing exertion to the maximum tolerated, usually with a cycle ergometer. Two key derived measures are maximum oxygen uptake (VO_{2max}) and the anaerobic threshold (AT),[7] which are then used to stratify patients' risk of adverse events. The key literature supporting CPET was written in 1993 by Older et al., who studied 187 patients undergoing elective major abdominal surgery.[8] Their results were as follows: 18% mortality (10/55) in patients with an AT <11 mL/min/kg, compared with 0.8% mortality (1/132) in patients with an AT >11 mL/min/kg. They concluded that patients with a low AT should be admitted to an intensive therapy unit preoperatively. In oesophageal surgery specifically, the evidence base is limited and conflicting; however, the use of CPET is increasing rapidly.

Following workup, patients are discussed at a tumour board or multidisciplinary team meeting and treatment plans are finalised. In general, patients suitable for curative treatment are then divided into those with early tumours that are potentially suitable for endoscopic resection and those with locally advanced tumours requiring systemic treatment and surgery. The remainder of patients are referred for palliative treatment, which may include a combination of local radiotherapy for palliation of dysphagia, systemic chemotherapy and endoscopic stenting.

ENDOSCOPIC RESECTION

In the last 10 years, endoscopic resection as a treatment option for early oesophageal (and gastric) cancers has rapidly advanced. There are potential advantages in this approach in that organ-preserving treatment can be undertaken, avoiding the risk of surgical complications and serious and lifelong implications of oesophagectomy in a patient group with multiple comorbidities. The key consideration in organ-preserving treatment is that cure rate is not unacceptably compromised by a technique that does not permit lymphadenectomy, and the high rate of early lymph node metastasis for oesophageal cancers precludes endoscopic treatments as curative for all but the earliest tumours. T1a tumours (i.e. those confined to the epithelium) and lamina propria lymph node metastases are found in 0–6% of patients undergoing surgical resection. This rises to 13–54% when tumours invade the submucosa (i.e. T1b tumours).[9,10] Further subdivision of T1b tumours has been proposed, differentiating those tumours with an invasion of ≤500 μm or one-third of the submucosa (T1bSM1) from deeper tumours with an invasion of one-third to two-thirds of the submucosa (T1bSM2) and of more than two-thirds of the submucosa (T1bSM3). There is some evidence that lymph node metastasis rates may be stratified along these lines, but definitive rates of lymph node metastasis according to this classification have historically been poorly documented and reported.

Several national guidelines have advocated for the use of endoscopic resection for early oesophageal tumours. In general, these suggest reserving endoscopic resection for patients with T1a disease or low-risk T1b disease (T1bSM1 with submucosal invasion <500 µm, without lympho-vascular invasion).[6,11–13]

SYSTEMIC TREATMENT

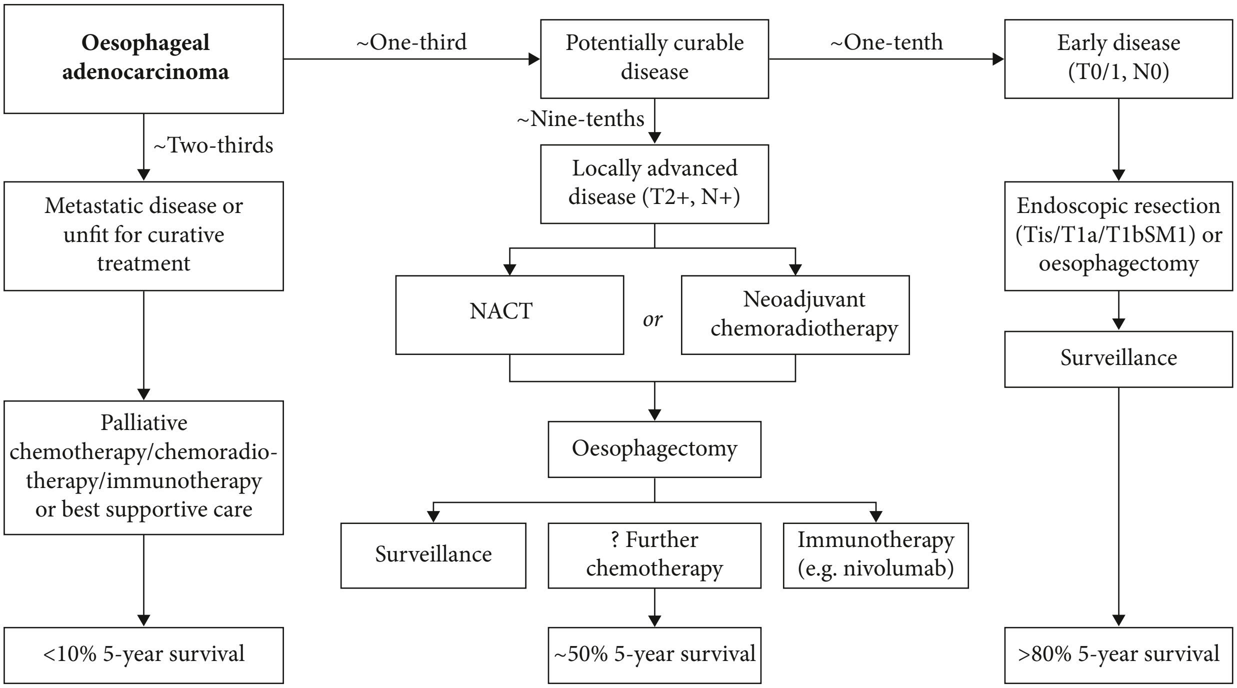
Notwithstanding the above discussion on endoscopic resection, neoadjuvant or perioperative systemic anti-cancer treatment followed by resection with surgery remains the standard of care for potentially curable oesophageal cancer. SCCs are particularly sensitive to radiation therapy and a proportion of these, particularly those in the proximal oesophagus, can probably be treated adequately without surgery by using definitive chemoradiotherapy (dCRT). The remainder may undergo neoadjuvant chemoradiotherapy based upon the CROSS trial[14,15] (i.e. carboplatin, paclitaxel and 41.4 Gy of radiotherapy), or platin-based chemotherapy, followed by surgery. High-level evidence comparisons of dCRT (with or without salvage oesophagectomy upon recurrence/disease progression) with neoadjuvant treatment and surgery are lacking.

For patients with adenocarcinoma, neoadjuvant/perioperative chemotherapy (NACT) and neoadjuvant chemoradiotherapy are both used extensively. In patients receiving NACT, current guidelines favour the use of the FLOT regimen (fluorouracil, leucovorin, oxaliplatin and docetaxel), which had superior outcomes to historic regimens (epirubicin, cisplatin and fluorouracil/capecitabine) in a recent seminal trial.[16] These patients will typically receive four cycles preoperatively and four cycles postoperatively, although only approximately 50% of patients receive postoperative cycles of chemotherapy.

Figure 9.4 illustrates a simplified treatment pathway for patients diagnosed with oesophageal cancer.

OESOPHAGECTOMY

Surgery remains the curative option for patients with oesophageal cancer and particularly patients with adenocarcinoma. In principle, the operation is to remove the tumour, its blood supply and lymphatic drainage *en bloc*. Oesophagectomy is performed almost exclusively for malignant disease. Benign conditions that occasionally warrant an oesophagectomy include long corrosive strictures and very late presentation of achalasia. When considering operative intervention for oesophageal carcinoma, the choice of incision and procedure is determined by tumour type, location, operability and the patient's cardiorespiratory status. For anatomical and functional reasons, the majority of the oesophagus is resected and then continuity is restored using a conduit, usually tubularised stomach, to function as the neo-oesophagus.



Oesophageal adenocarcinoma
~One-third
Potentially curable disease
~One-tenth
Early disease (T0/1, N0)
~Two-thirds
~Nine-tenths
Metastatic disease or unfit for curative treatment
Locally advanced disease (T2+, N+)
Endoscopic resection (Tis/T1a/T1bSM1) or oesophagectomy
NACT
or
Neoadjuvant chemoradiotherapy
Surveillance
Palliative chemotherapy/chemoradiotherapy/immunotherapy or best supportive care
Oesophagectomy
Surveillance
? Further chemotherapy
Immunotherapy (e.g. nivolumab)
<10% 5-year survival
~50% 5-year survival
>80% 5-year survival

9.4 Simplified treatment and outcome flow chart for patients with oesophageal adenocarcinoma. Tis, tumour *in situ*. ⏎

PRINCIPLES UNDERLYING OESOPHAGEAL CANCER SURGERY

Oesophageal lymphatic drainage is into a submucosal and peri-oesophageal plexus, in which lymph mixes from all levels of the oesophagus before draining to regional nodes. This has two important implications for the surgeon.

First, the possibility of submucosal extension within the lymphatic plexus must be considered, as this affects the margins of resection required. Even with a 10 cm macroscopic clearance, 10–20% of specimens will have involved margins. For this reason, a total or subtotal oesophagectomy is recommended, even for lower-third tumours. Lower-third adenocarcinomas may invade extensively into the stomach, and oesophagectomy may have to be combined with proximal partial or even total gastrectomy, with or without a splenectomy, to achieve an R0 resection. Similarly, oesophagectomy for a proximal oesophageal SCC may have to be combined with a pharyngectomy to obtain complete local tumour clearance.

Second, this mixing of lymph before drainage to nodes makes any form of very limited lymphadenectomy of little value. The lymphatic drainage from the oesophagus is divided into three fields – the abdominal, the intrathoracic and the cervical:

- A *one-field lymphadenectomy* involves resection of the intra-abdominal nodes draining the proximal stomach and distal oesophagus. This follows similar principles to the D2 lymphadenectomy described for proximal gastric cancer.
- A *two-field lymphadenectomy* describes the additional clearance of the intrathoracic nodes. These include the nodes in the tracheal bifurcation, the right paratracheal nodes and the pulmonary hilar nodes, in addition to the para-oesophageal and the para-aortic mediastinal nodes.
- A *three-field lymphadenectomy* includes, in addition, a neck dissection to clear the brachiocephalic, deep lateral and external cervical nodes.

While some surgeons recommend a formal two-field lymphadenectomy, others believe that positive nodes are mostly an indicator of incurable disease. A more extensive lymph node dissection improves staging, but the stage migration phenomenon makes it more difficult to interpret how much is gained in locoregional control and survival. There is also the issue of increased morbidity and mortality associated with a more major operation.

Surgery should be tailored to offer a patient the procedure that achieves minimal morbidity and mortality, while allowing macroscopic and microscopic clearance. The choice of operative intervention depends on a number of factors including tumour type, location, extent of lymph node involvement, fitness for surgery and surgeon preference. Resections are almost always carried out with curative intent. However, some patients who have involved margins (R1 resection) have good local disease control but die of distant disease before the tumour recurs locally.

Surgery for oesophageal cancer usually necessitates access to both the abdomen and the chest. Abdominal access is needed for dissection of the abdominal nodes and for preparation of the stomach as an oesophageal replacement. Thoracic access is needed for dissection around the primary tumour and for the macroscopically normal proximal and distal oesophagus to be excised, in addition to any thoracic node dissection. Increasingly, minimal-access and robotic approaches to either the abdominal or the thoracic resection, or to both, are being utilised in specialist units.

Four standard approaches to oesophagectomy are described below: the two-stage Ivor Lewis oesophagectomy, the three-stage McKeown operation, the transhiatal oesophagectomy and the left thoracoabdominal oesophagectomy. In recent years, there has been continued movement towards less invasive approaches to oesophagectomy. The transhiatal dissection, thus sparing the patient the morbidity of a thoracoabdominal or a separate thoracotomy incision, was followed by combinations of laparoscopic and thoracoscopic minimally invasive two-/three-stage procedures. Evidence for the benefit of different approaches is conflicting and limited. Generally, in Western societies, the Ivor Lewis operation tends to be more favoured, with three-phase oesophagectomy more common in Asia where SCC with a corresponding higher rate of cervical lymph node metastasis is prevalent.

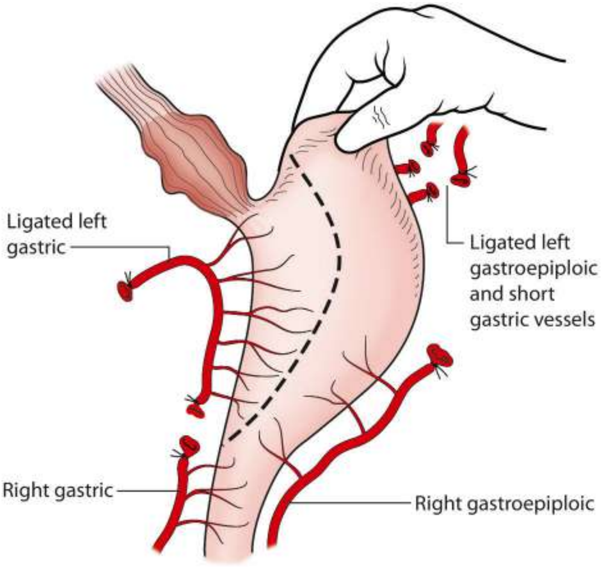
IVOR LEWIS OESOPHAGECTOMY

An Ivor Lewis oesophagectomy consists of two separate operative phases, first in the abdomen and then in the right chest, through either open or minimally invasive approaches. The McKeown three-stage oesophagectomy is similar but then proceeds to a neck dissection.

Abdominal component

The patient is first placed in the reverse Trendelenburg position with approximately 15° of head-up tilt. Some surgeons favour standing between the legs, particularly if undertaking a laparoscopic approach. An upper midline laparotomy or rooftop incision provides adequate access to the upper abdomen if conducting an open operation. If performing a laparoscopic resection, four ports and a liver retractor will typically be used. A full peritoneal examination is then performed to check for evidence of advanced disease in the form of peritoneal metastases in particular, which might not have been apparent on imaging. This is particularly important in lower-third oesophageal cancers, which have a greater propensity to spread intra-abdominally. The presence of liver metastases, retroperitoneal lymph nodes or disseminated peritoneal disease means that no benefit is likely to be obtained by proceeding with oesophagectomy, and treatment should be aimed at palliative symptomatic relief.

The greater omentum is mobilised outside the right gastroepiploic vessels, which must be preserved as an arterial supply to the stomach remnant. The left gastroepiploic and short gastric vessels are then divided along the greater curve, taking care not to damage the gastric wall or spleen (Figure 9.5). The stomach is placed on stretch, allowing the gastrohepatic ligament to be incised. The right gastric artery is preserved, which, together with the right gastroepiploic artery, is the blood supply to the gastric remnant that will be used as the conduit. The duodenum is Kocherised to maximise the length of the gastric conduit and minimise tension at the anastomosis in the chest. The left gastric vein and artery are then identified and ligated near their origin, incorporating a broad lymphadenectomy at the coeliac axis extending to strip nodes and lymphatics on both the common hepatic and the splenic arteries.



9.5 Oesophagectomy: preparation of a gastric conduit. The blood supply for the conduit is from the right gastric and gastroepiploic arteries. The left gastric, the short gastric and the left gastroepiploic arteries have all been ligated. Gastric transection along the dotted line enables the cardia and the lesser curve and cardiac nodes to be removed *en bloc* with the tumour. The hand is holding the high point of the stomach, which will be used for the anastomosis. ⏎

The vagi will be divided during the oesophagectomy and, therefore, some surgeons perform a pyloroplasty to reduce delay in gastric emptying. An alternative favoured by some surgeons is a pyloromyotomy, which may be associated with a lower incidence of bile reflux and alkaline gastritis. Evidence for either of these approaches is conflicting and not performed by all surgeons in all cases.

The oesophageal hiatus is then mobilised, allowing a soft tubular drain to be passed around the GOJ. If the tumour involves the hiatus, a cuff of diaphragm surrounding the tumour may be removed *en bloc* to ensure adequate margins of resection. Traction on the drain aids mobilisation of the distal oesophagus under direct vision and, with good retraction, cranial dissection under direct vision can be performed up a considerable length in the mediastinum. The pleura will often be opened on both sides during this dissection. If performing a laparoscopic approach, communication with the anaesthetist is vital, as the capnothorax that occurs can be mistaken for a CO_2 embolus if not anticipated.

The stomach is then tubularised into a suitable conduit using a linear stapler (see Figure 9.5). A 5 cm margin from the tumour should be targeted and the conduit shaped to approximately 4 cm in width. The highest point on the fundus is identified and will be used for the anastomosis. It is therefore possible to remove the GOJ and the greater part of the lesser curve without reducing available length. This has the advantage of removing upper gastric drainage nodes to which a distal oesophageal cancer may spread. The staple line of the gastric tube can be oversewn using an inverting stitch. Some surgeons advocate a feeding jejunostomy placed into the first or second loop of jejunum to allow early postoperative feeding and/or nutritional support following surgery.

Thoracic component

The patient is then placed in a left lateral position, which allows a right posterolateral thoracotomy to be performed through the fourth or fifth intercostal space. A double-lumen endotracheal tube allows the right lung to be collapsed, with ventilation maintained through one-lung anaesthesia. Minimally invasive approaches again typically require four ports, with the most inferior converted to an extraction site at the end of the procedure.

The inferior pulmonary ligament is divided and the lung gently retracted. The mediastinal pleura overlying the oesophagus is divided and the azygos vein identified and double ligated before division. Dissection continues to free the oesophagus, and all of the para-oesophageal lymph nodes are included with the resected specimen. Oesophageal arterial branches are divided with advanced bipolar instruments or between clips. During superior dissection, care must be taken to avoid damaging the recurrent laryngeal nerve. Many surgeons routinely identify and ligate the thoracic duct immediately above the diaphragm, on the right lateral aspect of the descending aorta, to reduce the subsequent incidence of chylothorax. Knowledge of the course of the duct and its potential anatomical variations is important if damage is to be avoided intraoperatively. The thoracic duct is the principal lymphatic drainage system. It commences as the cisterna chyli, in the midline, at the level of the 12th thoracic vertebra to the right of the aorta. It passes through the diaphragmatic hiatus into the chest and ascends on the right side of the thoracic spine until the level of the fourth or fifth thoracic vertebra, where it crosses posterior to the aorta to ascend on the left side of the oesophagus. In the root of the neck, just above the level of the clavicle, it arches forwards and passes anterior to the left subclavian and common carotid arteries, eventually emptying into the left subclavian vein near its junction with the left internal jugular vein. The thoracic duct is thus particularly vulnerable to injury when the supra-aortic oesophagus is removed or when there is dissection around the right side of the aorta, as when the para-aortic mediastinal nodes are retrieved. Although some surgeons recommend routine ligation or resection of the thoracic duct during oesophagectomy, others are selective. Those who are selective are most likely to ligate the duct when a right thoracotomy is employed for an oesophagectomy that is to be combined with a more extensive intrathoracic lymphadenectomy.

Particular care is taken around the right and left bronchi and trachea, as the airway is particularly susceptible to diathermy injury, which can be catastrophic and can present either immediately or in a delayed fashion. Typically, lymph node dissection is carried up to the subcarinal lymph node packet, which has a tendency to bleed, which on occasion can be problematic. Once the intrathoracic oesophagus has been adequately mobilised, the stomach is fully delivered into the chest via the hiatus. The proximal and distal resection limits are identified and the specimen extracted.

The anastomosis can then be conducted in a number of ways, including circular stapled, linear stapled or hand sewn if preferred. The author's practice is to conduct a linear-stapled anastomosis. The proximal oesophagus is stapled off and the tubularised stomach is secured proximal to this with a stay suture. An oesophagotomy is then performed to a size to permit the stapling device, and the oesophageal mucosa is sutured in place to prevent its retraction. A gastrotomy is then made and opposed to the oesophagotomy with further stay sutures. A linear stapler then performs the anastomosis with the resultant defect closed in two layers with absorbable sutures.

Typically, a single basal chest drain is then placed, although an apical right chest drain or left chest drain may also be utilised in certain scenarios. A paravertebral/extrapleural local anaesthetic catheter is placed under direct vision and may obviate the need for a thoracic epidural. The thoracotomy or mini-thoracotomy is then closed in layers with strong absorbable sutures.

McKEOWN OESOPHAGECTOMY

Typically, the thoracic phase of the McKeown operation is performed first in the left lateral position before placing the patient supine to conduct the abdominal and finally the neck dissections. The abdominal and thoracic phases of the operation are similar to the dissection phases in an Ivor Lewis oesophagectomy, with the dissection in the right chest carried proximally into the root of the neck.

Attention is then turned to the neck. The cervical oesophagus is accessed by making an incision along the anterior border of the sternocleidomastoid. A low transverse cervical incision is a suitable alternative. The skin, subcutaneous tissue and platysma are incised. The carotid sheath is identified and retracted laterally and the trachea is retracted medially. The middle thyroid vein and inferior thyroid artery may need to be ligated and divided to avoid avulsion during dissection. It is imperative to avoid damaging the recurrent laryngeal nerve as it runs in the tracheo-oesophageal groove, and retractors should not be inserted blindly.

Posterior finger dissection will identify the prevertebral fascia and allow it to be separated from the posterior oesophageal wall. The recurrent laryngeal nerve is then identified and protected. Staying close to the oesophageal wall during anterior and right lateral dissection will reduce the risk of damage to the nerve and to the membranous posterior wall of the trachea. If a nasogastric tube is *in situ*, this will be helpful for this part of the dissection. A soft drainage tube is inserted around the oesophagus. This aids further dissection and allows the cervical oesophagus to be elevated out of the incision. Small oesophageal arteries that are avulsed during these manoeuvres usually retract and thrombose spontaneously.

The level of the cervical oesophageal transection is then decided. Stay sutures are inserted proximal to this point into the lateral and medial walls. A latex drain is sutured to the oesophagus, distal to the line of transection. The nasogastric tube is then retracted proximal to the line of transection and the cervical oesophagus is divided cleanly using straight scissors, a scalpel or a stapling device. The oesophagus is then removed from below via the diaphragmatic hiatus.

The latex drain sutured to the oesophagus is thus drawn through the posterior mediastinum. It is then detached from the oesophagus and left lying with one end at the cervical opening and one end in the abdomen, where it will serve as a guide to bring up the oesophageal conduit from the abdomen.

The latex drain is now attached to the apex of the gastric conduit and used to guide the stomach up into the neck. This is aided by gentle manipulation of the stomach through the posterior mediastinum by the surgeon's hand. It is important to avoid gastric torsion. The anastomosis can be created using a circular stapling device, introduced through a gastrotomy. However, with the excellent exposure provided by a cervical approach, a hand-sewn anastomosis may be preferred. A small anterior opening is made near the highest point of the fundus and the anastomosis fashioned with a single layer of interrupted sutures, using an absorbable suture material. The posterior layer of sutures is inserted first. The nasogastric tube is then carefully advanced across the anastomotic line before closing the anterior layer. A small suction drain is placed close to the anastomosis prior to closing the neck incision.

TRANSHIATAL OESOPHAGECTOMY

Transhiatal oesophagectomy involves abdominal and cervical incisions only, thus avoiding a thoracotomy. The stomach, GOJ and distal oesophagus are mobilised via the abdominal incision. The intrathoracic component of the oesophagus is freed distally through the diaphragmatic hiatus and proximally via the cervical incision. The resected oesophagus is then reconstructed using the gastric remnant or an intestinal loop as an oesophageal conduit. This is passed through the chest via the posterior mediastinum, allowing it to be anastomosed to the cervical oesophagus without tension.

After conducting the abdominal part of the operation as per an Ivor Lewis operation, blunt dissection into the mediastinum is continued, typically by hand. Staying close to the oesophageal wall, the posterior oesophagus is separated from the prevertebral fascia. Anterior blunt dissection is then performed, again staying close to the oesophageal wall and avoiding cardiac displacement, which may give rise to arrhythmias and hypotension. Communication with the anaesthetist is crucial at this point. If any haemodynamic instability ensues, it will usually revert to normal if the hand is removed from the thorax, and all dissection must be halted until the patient has stabilised. The lateral oesophageal attachments must also be divided. Neck dissection/anastomosis as in the McKeown oesophagectomy can then be performed.

THORACOABDOMINAL OESOPHAGECTOMY

This is a suitable approach for tumours involving the distal oesophagus, GOJ and gastric cardia. The patient is placed in a right lateral decubitus position with the left arm flexed at 90° to the body and placed in an arm rest. It is a one-stage procedure that utilises a single incision, with the initial transverse or oblique abdominal incision extended over the left chest. The operating table is rotated as the surgical field moves from abdomen to chest, or vice versa. The choice of intercostal space is decided on exploring the abdomen and may be through the sixth, seventh or eighth space. The incision can extend to the edge of the erector spinae muscle, with the intercostal muscles incised using diathermy to achieve good haemostasis. The cartilage of the costal margin is divided, while the rib above or below the chosen space may be divided to provide greater access. Once the pleural cavity is entered, a rib retractor is inserted.

The diaphragm is incised to the oesophageal hiatus in a circumferential manner to reduce the potential for damage to the phrenic nerve or its branches. A radial incision carries a significant risk of diaphragmatic paralysis. The inferior phrenic artery is ligated. Adhesions to the lung base and the lower part of the pulmonary ligament are divided so that the lung can be retracted upwards. The stomach is then mobilised as described previously and the lower oesophagus is freed through a longitudinal incision in the parietal pleura between the aorta and the pericardium. The vagi are identified and divided. Encircling the distal oesophagus with a soft drainage tube aids its subsequent dissection. Vessels should be divided only if this is essential for oesophageal mobilisation. The thoracic duct is ligated immediately above the diaphragm to prevent a chylothorax. Division of the diaphragm is now completed and the cuff is removed if this is required to ensure tumour clearance.

The thoracoabdominal approach is often chosen for more advanced GOJ tumours where an oesophagectomy must be combined with a gastrectomy. However, the remaining stomach can often still be used as the oesophageal conduit, especially as it does not need as much length as it would for a cervical anastomosis. The division of the stomach and the formation of the gastric conduit are then undertaken in a similar manner to that described for the Ivor Lewis operation. The anastomosis is performed beneath the aortic arch, and again this can be undertaken with a circular stapler or by a hand-sewn technique. If a total gastrectomy is necessary, reconstruction is usually with a Roux loop and an oesophagojejunal anastomosis.

The diaphragm is closed with interrupted absorbable sutures. At the diaphragmatic hiatus, the gastric tube or other conduit is sutured to the diaphragmatic edge to prevent herniation. Two drains are inserted into the chest, with a straight 28-French drain directed to the apex and a 32-French angled drain directed towards the base, prior to left lung re-inflation. Division of the costochondral cartilage may be a source of pain postoperatively. The divided edges must be closely approximated to prevent them rubbing together, with some surgeons favouring a miniplate attached by screws. Alternatively, 2 cm of costochondral cartilage is removed completely to prevent contact and friction.

Postoperative care is similar to that for transhiatal oesophagectomy, but the thoracic incision makes these patients more prone to respiratory complications, including atelectasis and pneumonia. Pain relief and physiotherapy are therefore extremely important.

SURGICAL APPROACH IN OESOPHAGECTOMY

The use of minimal-access (often called minimally invasive) and robotic approaches for oesophagectomy has rapidly expanded over the last 10 years. In many specialist centres, minimal-access techniques are routine, with open operations performed rarely and only for the most advanced tumours or when patients have previously undergone extensive surgery. A number of trials have investigated how different approaches influence outcome. The MIRO trial[17–19] compared hybrid oesophagectomy (laparoscopic abdomen and open chest) to open oesophagectomy, suggesting reduced pulmonary morbidity with equivalent overall survival. The TIME trial[20] showed similar results for a fully minimally invasive oesophagectomy (MIO [laparoscopic abdomen and thoracoscopic chest]) with reduced blood loss in patients who had minimal-access surgery. The ROMIO trial[21] compared open, hybrid and MIO approaches, incorporating an assessment of surgical quality to ensure consistency of approach; this trial demonstrated no differences in outcomes for approach. Similar trials using robotic surgery are currently under way, with several having reported early results. The ROBOT trial[22,23] compared open MIO with robot-assisted minimally invasive oesophagectomy (RAMIO), demonstrating fewer complications in patients undergoing RAMIO, with equivalent survival. The RAMIE trial[24] from China compared MIO with RAMIO, demonstrating similar complications, with less operative time and increased lymph node yield in the patients undergoing RAMIO. The ROBOT-2[25] and REVATE[26] trials are currently under way investigating MIO versus RAMIO in Western populations. Robot-assisted cervical oesophagectomy, where, after performing abdominal mobilisation, the mediastinal dissection/anastomosis is performed through a neck incision, is a further promising technique that has the potential to further reduce morbidity. However, experience is confined to a very small number of centres at present.

Oesophagectomy is a technically demanding operation, particularly when operating within the chest, and lends itself well to robotic approaches with the increased precision available. Nonetheless, in the absence of definitive evidence showing any long-term benefits of one approach over another, the best operation is the one that allows the safe removal of the tumour without compromising oncological principles with acceptable unit-level outcomes.

PALLIATIVE MANAGEMENT OF OESOPHAGEAL AND GOJ TUMOURS

In the absence of any screening programmes, a high proportion of patients with gastric and oesophageal carcinomas present with advanced unresectable disease. Their management is principally palliative, aimed at symptom control. Some patients, despite having early cancer, may be unsuitable for radical surgery due to coexisting morbidity, and this subgroup also have to be managed in a palliative manner.

In patients with unresectable and metastatic disease, the addition of chemotherapy may prolong survival, but this must be weighed against the patient's fitness for such treatment and the quality of life obtained. Radiotherapy may also be used to ameliorate pain from metastatic bone disease. However, the predominant and most distressing symptom for patients with advanced oesophageal and proximal gastric cancer is dysphagia. Fortunately, there are several effective palliative options. A tumour can be stented, reduced in bulk or bypassed. Non-surgical debulking of a tumour can be achieved by a variety of methods, either in conjunction with a stent or as an alternative if stent insertion is not possible.

Self-expanding covered metallic *oesophageal stents* will usually enable a patient to resume a liquid or semi-solid diet. In principle, a soft guide wire, followed by a self-expanding stent, is placed through the lumen of the tumour under radiological control or endoscopic visualisation. Oesophageal stent insertion may not be possible if the patient has a proximal oesophageal tumour, near the cricopharyngeal sphincter.

Palliative radiotherapy is effective, but initially dysphagia may be exacerbated by oedema and no benefit may be seen for up to 2 months. External-beam radiotherapy will require multiple hospital visits for the most effective fractionated regimes. Brachytherapy, which involves the placement of a radioisotope within the lumen of the tumour, is another option. Inherent risks of radiotherapy include the development of a tracheo-oesophageal fistula and stricture formation.

Laser destruction of exophytic tumours can effectively palliate dysphagia, but its use has been largely superseded by stents.

Photodynamic therapy relies on intravenously administered photosensitisers, which are taken up selectively by malignant cells, where they are then activated by light. Oxygen free radicals are generated, which induce tumour necrosis. The photosensitive agent is retained in tissues for several weeks and sunburn is a common complication of this procedure.

Rarely, patients with limited metastatic disease may be suitable for potentially curative treatment. The concept of oligometastic disease has existed for a number of years and in, for example, colorectal cancer, resection of synchronous liver metastases is common. The FLOT-5/RENAISSANCE trial[27] is currently investigating if, for patients with oligometastatic oesophagogastric cancer, chemotherapy followed by surgical resection of the primary metastases results in better outcomes than chemotherapy alone.

OESOPHAGEAL CONDUITS

Resection and replacement of the oesophagus have been a source of great challenge to surgeons. The preferred conduit is usually the stomach, provided that this reaches the proximal oesophagus with a good blood supply and without undue tension. If the patient has undergone a total gastrectomy, alternatives such as colonic interposition or jejunal grafts will have to be considered. The principles of the conduit are the restoration of gastrointestinal continuity with an adequate lumen and satisfactory function, while keeping the incidence of reflux, with the danger of aspiration, to a minimum.

Stomach

The stomach is the conduit of choice for oesophageal replacement in almost all situations. Following oesophageal surgery, most patients have a significant gastric remnant of a size that will reach the proximal oesophagus. Kocherisation of the duodenum and division of the short gastric and left gastric vessels add to the length available for mobilisation. One advantage of the stomach over other grafts is the need for a single anastomosis. There is, however, the risk of ischaemic necrosis at the apex of the gastric tube and, even in the absence of frank necrosis, a marginally adequate perfusion may contribute to anastomotic breakdown. A gastric conduit is associated in the long term with an increased risk of proximal oesophagitis and stricture.

Colon

The use of a colonic conduit involves three anastomoses, but the procedure is associated with a lower incidence of postoperative reflux symptoms, and patients may have an improved quality of life. Preoperative colonoscopy may be advisable to exclude underlying bowel disease. Right, transverse or left colon can be used as a colonic conduit. The right colon is more satisfactory and, if the ileocolic segment is used, there is little discrepancy between the lumen of the terminal ileum and the cervical anastomosis, ensuring a satisfactory end-to-end anastomosis. The terminal ileum and the distal transverse colon are divided and an ileocolic anastomosis constructed. The ileocolic vessels are divided and the conduit relies on its blood supply from the middle colic vessels and, variably, also from the right colic vessels, although the latter may have to be divided to provide sufficient mobility.

Jejunal Roux loop

This is a satisfactory alternative conduit when a lower-third oesophagectomy has been combined with a total gastrectomy for a tumour of the cardia. A left thoracoabdominal incision has usually been employed and the anastomosis is below the aortic arch. This, however, is generally as high as it is possible to bring a Roux loop.

Jejunal interposition

A segment of jejunum, with a suitable mesenteric vessel, is identified by mesenteric transillumination. The segment of jejunum, with its vascular supply still intact, is divided and the small bowel is anastomosed to restore intestinal continuity. The isolated segment can then be used as an isoperistaltic interposition graft. However, its blood supply will seldom allow it to be brought up for an anastomosis above the aortic arch. When the segment is needed at a higher level, it must be used as a free graft, but this requires considerable expertise and microvascular experience. Jejunal interposition is therefore usually reserved for situations where other options are not possible or have failed. Its routine use is restricted to pharyngo-oesophageal replacement. As the small intestine does not tolerate prolonged periods of ischaemia, it is usual to isolate the graft but to leave it *in situ* until all other dissection is completed, the recipient vessels have been identified and everything is prepared for the microvascular reconstruction.

Route for the conduit

An oesophageal conduit can be brought up to the neck via the posterior mediastinal, the retrosternal or the subcutaneous route.

Posterior mediastinal route

This is the route taken by the native oesophagus and is therefore preferred for a conduit in most circumstances. It is slightly shorter than the alternatives, and the proximal oesophagus and the conduit are well aligned for the anastomosis. When the native oesophagus is removed transhiatally, a conduit can be tunnelled through the posterior mediastinum without a thoracotomy, as described above. However, this route may not be suitable when it is the site of dense adhesions. There may have been posterior mediastinal sepsis from a previous oesophageal perforation or failure of a previous conduit from ischaemic necrosis or anastomotic leakage. Corrosive damage, radiotherapy fibrosis and residual tumour can similarly exclude the posterior mediastinum.

Retrosternal (anterior mediastinal) route

This is usually the preferred non-anatomical route when the posterior mediastinum is unsuitable. A midline retrosternal tunnel can be created by blunt finger dissection through abdominal and cervical incisions. A narrow, malleable intestinal retractor is then passed up the tunnel, keeping the tip immediately deep to the sternum. The conduit is then guided up to the cervical incision. The strap muscles are divided to allow the oesophageal substitute to pass to the oesophagus for an anastomosis. Unfortunately, the angulation of the conduit onto the cervical oesophagus and its abnormal anterior relationship to the trachea make swallowing feel unnatural and unpleasant.

Subcutaneous (presternal) route

This route requires an even longer conduit than the retrosternal alternative and is nowadays used only occasionally. It may, however, avoid any possible respiratory compromise in a patient with very poor lung function. It may also have to be considered in a patient whose anterior mediastinum is unsafe because of adhesions between the heart and a median sternotomy scar from previous cardiac surgery.

OTHER TUMOURS OF THE OESOPHAGUS

Other tumours of the oesophagus are rare. Of these, leiomyoma is most common, with others such as gastrointestinal stromal tumour (GIST), schwannoma, leiomyosarcoma and haemangioma rarely encountered. These are frequently identified incidentally, although may cause dysphagia if large. Leiomyomas typically occur in the distal two-thirds of the oesophagus and are multiple in 5% of cases. Treatment is usually limited to symptomatic patients, if there is diagnostic doubt or when tumours are large (>5 cm). Typically, these tumours are enucleated (shelled out), which can be done with either thoracotomy or thoracoscopic approaches. Small (<3 cm) lesions may also be considered for endoscopic resection in centres with proficient, highly skilled endoscopists in advanced resectional techniques. Diagnosis is typically confirmed by EUS, and biopsies are not routinely advised, as this disrupts tissue planes, making enucleation challenging. Oesophageal GIST may also be treated by enucleation if small; however, the consensus is less clear here and these patients may require a formal resection.

GASTRIC CANCER

Gastric cancer, despite a falling incidence in the Western world, is still a major cause of morbidity and mortality. In recent years, the anatomical location of gastric cancer appears to have shifted from the antral portion to a more proximal part of the stomach, including involvement of the GOJ. In Japan, gastric cancer is the most common malignancy in both men and women, and this has led to the introduction of mass screening programmes to facilitate early detection. This approach appears to have successfully reduced mortality from the disease. *Early gastric cancer* is now defined as cancer restricted to the mucosa and submucosa (T1). Around one-third of Japanese patients are diagnosed at this stage as a result of extensive surveillance programmes.

Outcomes for patients who present with T2 disease and no evidence of metastatic spread are also good but, unfortunately, many patients present with more advanced disease. When a patient is diagnosed with gastric cancer, it must first be determined whether a potentially curative resection is possible. It is important to identify patients who will not benefit from any surgical intervention prior to a laparotomy. A CT scan is pivotal in preoperative staging, as it may show liver or omental deposits or the involvement of preaortic nodes. Endoscopic ultrasonography is used in some centres to measure the depth of invasion and the involvement of adjacent nodes. PET-CT scans, as in the workup for oesophagectomy, are increasingly used in staging prior to gastrectomy but are not yet formally recommended.

The management of all gastric cancers should now be with a multidisciplinary approach. Many patients will enter a palliative course after staging, and those who come to a potentially curative resection will often be advised to have perioperative neoadjuvant and adjuvant chemotherapy.

DIAGNOSTIC LAPAROSCOPY

Diagnostic laparoscopy is particularly valuable in the identification of peritoneal seedlings and peripheral liver metastases that are too small to identify by CT scanning. At laparoscopy, the surface of the liver and the peritoneum over the falciform ligament and under the diaphragm should be examined carefully for peritoneal deposits. Any suspicious lesions should be biopsied and ascitic fluid sent for cytological examination to determine if malignant cells are present. While this places a further percentage of patients into a palliative category, it avoids unnecessary laparotomies and also helps to identify those with the greatest potential for surgical cure. Despite investigations, gastric cancer is understaged preoperatively in approximately 20% of patients.

GASTRECTOMIES FOR CANCER

The principle of operative intervention for gastric cancer is to achieve complete resection of the primary tumour with an *en bloc* regional lymphadenectomy. A total gastrectomy may be indicated when the extent or location of the primary tumour is such that adequate margins of resection (i.e. 4–6 cm) are not possible with a subtotal gastrectomy. This particularly occurs with proximal gastric tumours and extensive lesions, including patients with linitis plastica. Macroscopic and microscopic clearance of the tumour (an R0 resection) should not be compromised by performing a subtotal gastrectomy when a total gastrectomy is indicated.

Gastric cancer has a high propensity for regional lymphatic spread. Historically in the UK, a gastrectomy for cancer included only the perigastric first-tier nodes. However, in Japan, the patterns of lymphatic spread were studied and surgeons pioneered more radical lymph node dissection.[1] These more extensive operations appeared to be associated with better long-term survival. Initially, there was caution in the West, mainly related to concerns regarding greater operative morbidity and mortality. Pioneers did, however, encourage adoption of the technique in selected patients after visits to Japanese cancer units,[28] and the potential advantages of a more radical lymphadenectomy are now generally accepted.

Not every patient is suitable for this surgery, and preoperative assessment of a patient's cardiac, respiratory and nutritional status is particularly important when the lesion is in the gastric cardia or near the GOJ, as radical excision may necessitate a thoracic incision. Preoperative staging is also very important so that major surgery can be avoided in patients for whom gastrectomy offers no benefit.

Extent of the gastric resection

In early gastric cancer, a conservative resection may be considered, but, for most patients, a subtotal or a total gastrectomy will be necessary for a potentially curative resection, with many tumours of the cardia requiring an additional distal oesophagectomy to achieve an R0 resection.

Subtotal or total gastrectomy

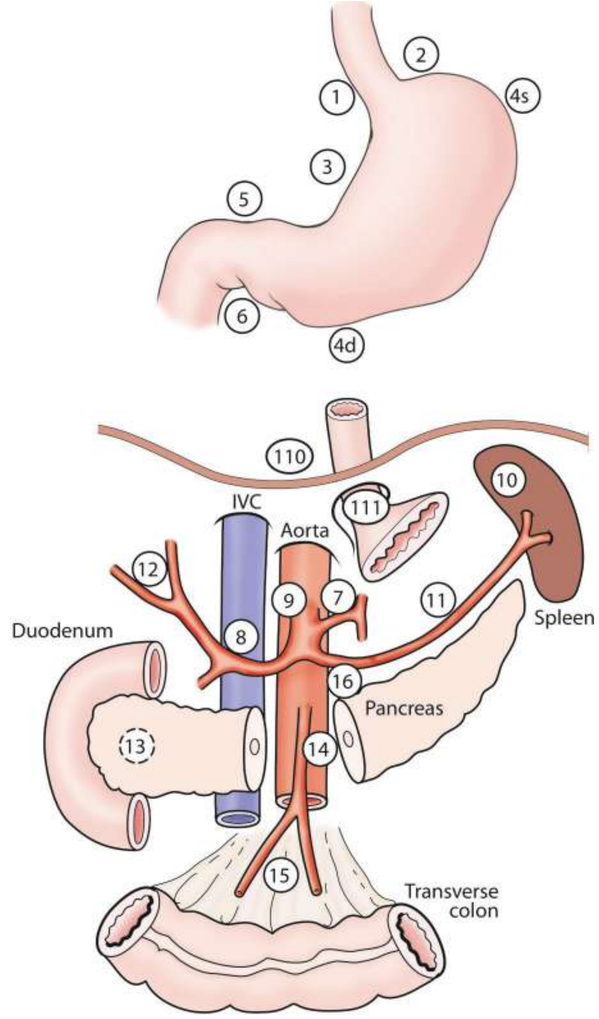
Gastric cancer spreads in the submucosal plane. At presentation, this infiltration may involve the whole of the stomach (linitis plastica) and, in these cases, the tumour infiltration may even extend into the duodenum or oesophagus. In most patients, however, there is a palpable edge to the tumour, and transection 5 cm clear of this edge will usually be free of tumour infiltration. Thus, in distal gastric cancer, a partial gastrectomy can offer an R0 resection. The proximal gastric remnant should include at least 2 cm of the lesser curve, and the palpable edge of the tumour must therefore be 7–8 cm from the GOJ. A total gastrectomy thus becomes necessary for any tumour that encroaches to within 7–8 cm of the GOJ, if positive resection margins are to be avoided. In theory, a proximal gastric cancer can be resected with adequate margins and the antrum and pylorus preserved. However, functional results after a proximal subtotal gastrectomy and anastomosis of the distal stomach to the oesophagus are poor, mainly due to alkaline oesophageal reflux. Most surgeons recommend a total gastrectomy in these circumstances.

Limited excision of early gastric cancer

Most of the research on early gastric cancer with curative intent local resection has come from Japan. Endoscopic resection or laser ablation may be suitable for very superficial cancers. Resection techniques are superior, as ablative procedures preclude any histological assessment. Endoscopic mucosal resection is performed via a two-channel flexible endoscope. The lesion is lifted by submucosal saline injection, grasped with forceps and snared with a diathermy loop. The more accurate submucosal dissection on the surface of the muscle coat can be achieved under direct vision using an endoscopic electrosurgical knife.[7] Accurate preoperative assessment of the depth of invasion is crucially important, as fewer than 5% of mucosal cancers have nodal metastases, whereas, in cancers that invade the submucosa, up to 25% may have nodal metastases and around 5% may have metastases in second-tier nodes. Limited full-thickness gastric resection, with sentinel node biopsy to exclude those requiring a more radical resection, is another option.[8]

Extent of the lymphadenectomy

Lymphatic spread can occur early in gastric cancer, and lymphatic recurrence in the gastric bed is a major area of failure. In some patients, this occurs without simultaneous haematogenous or peritoneal spread, which raises the possibility that a more radical lymphadenectomy could have been curative. The Japanese have led the world in this concept and have extensively mapped the patterns of lymph node metastases. Gastric lymph nodes have been subdivided into numbered anatomical groups or 'stations' (Figure 9.6) and then considered as 'tiers' of nodes. The stomach is also subdivided into an upper section (C), a middle section (M) and a lower section (A). The tumour is then classified according to the section of stomach in which it arose and also any sections into which it has spread. For example, a localised antral tumour is designated 'A' and a middle-section tumour that has spread to the cardia is designated 'MC'. The tiers of lymph nodes differ according to the position of the tumour. The first-tier nodes are perigastric nodes close to the tumour and the second-tier nodes include both nodes along the proximal section of the arteries supplying the section of stomach involved in the malignancy and other more distant perigastric nodes. For example, stations 3, 4d, 5 and 6 are the first-tier nodes for an antral cancer and stations 7, 8, 9 and 1 are the second-tier nodes. The concept of D1, D2 and D2/D3 gastrectomy developed from this. A D1 gastrectomy implies the excision of all first-tier nodes, a D2 gastrectomy implies the excision of all first- and second-tier nodes and a D2/D3 gastrectomy implies the additional removal of some third-tier nodes. The approach to lymphadenectomy in Japan became far more radical than in the West and very impressive survival figures were obtained. However, the true benefit from the more major surgery is less than it immediately appears. When a more radical lymphadenectomy is undertaken, metastases may be found in nodes that would not have been available for analysis after a standard, less radical operation. This places the cancer in a more advanced stage, and the apparent benefit from excision of more nodal tissue is then fallacious and merely a *stage migration phenomenon*.



9.6 Gastric lymph node stations. 1, right cardiac; 2, left cardiac; 3, lesser curve; 4s, proximal greater curve; 4d, distal greater curve; 5, suprapyloric; 6, subpyloric; 7, left gastric artery; 8, common hepatic artery; 9, coeliac axis; 10, splenic hilar; 11, splenic artery; 12, hepatoduodenal; 13, retropancreatic; 14, root of mesentery; 15, middle colic artery; 16, para-aortic; 110, para-oesophageal; 111, diaphragmatic. IVC, inferior vena cava. ⏎

The standard subtotal D2 gastrectomy for antral cancer, which excises all first- and second-tier nodes, is an operation that has been generally adopted. However, in proximal gastric cancer, which is much more common in the West than in Japan, the first-tier nodes are 1, 2, 3 and 4s and the second-tier nodes are 4d, 7, 8, 9, 10, 11, 5 and 6. Station-10 nodes are in the hilum of the spleen and station-11 are along the splenic artery, behind the pancreas. A full D2 gastrectomy for proximal cancer is, therefore, a very major procedure. It involves either the addition of a splenectomy and distal pancreatectomy or a difficult dissection if these nodes are to be retrieved but the organs retained. Data from the Dutch D1/D2 trial showed that D2 lymphadenectomy is associated with lower locoregional recurrence and gastric cancer-related death rates compared with D1. However, data from the same trial showed that the D2 procedure was associated with significantly higher overall mortality, morbidity and re-operation rates. Any gain in long-term survival must be balanced against a higher perioperative mortality. However, as high-volume centres can offer a lower morbidity and mortality, at least partly associated with the highly specialised spleen-preserving D2 technique, a D2 lymphadenectomy is now the recommended surgical approach for patients with resectable gastric cancer.[9] The Italian analyses of their results has confirmed that, in specialised centres, the complication rates after D2 dissections are much lower than that reported from the original multicentre data and that early morbidity and mortality compare favourably with those after D1 dissections.[10]

The risk/gain balance for the individual node stations has also been calculated, and this may be more important than a rigid classification into node tiers. This calculation is based on the likelihood of metastases within the nodes of a particular station, the possible survival benefit from removing them and the additional mortality and morbidity from doing so. Current trends and data, particularly from Far Eastern centres, increasingly favour a less invasive approach, with omentectomy, bursectomy, and excision of splenic hilar nodes less frequently performed.

Serosal spread

This is a common area of failure in gastric cancer, and the reason that laparoscopy should be considered as part of the staging procedure in order to save patients with macroscopic peritoneal deposits from attempts at non-curative major surgery. Most patients in the West present with gastric cancer that has invaded the serosa. The peritoneal cavity is already contaminated with malignant cells, even if there are no visible metastatic deposits, and this is reflected in a significantly worse prognosis. Most of the lesser sac peritoneum is excised in a D2 gastrectomy, and this may be of some value in posterior tumours that have only contaminated this area. Intraoperative and postoperative intraperitoneal chemotherapy may have a place when there is serosal invasion. In some units in Japan, this is used routinely if peritoneal malignant contamination is confirmed by identification of free malignant cells on peritoneal cytology. However, the benefit of this approach either for positive cytology alone or for small peritoneal seedlings is still under review.

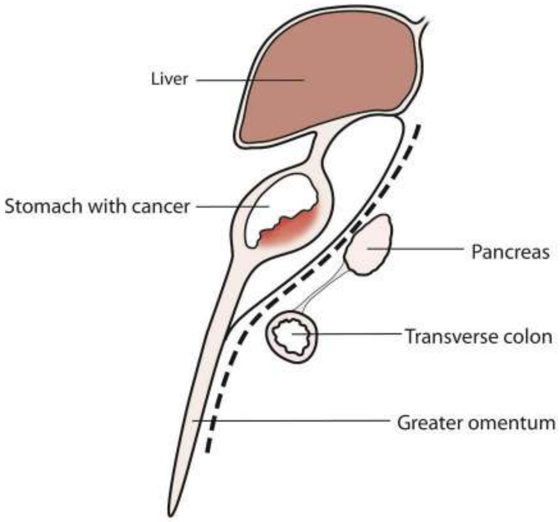
Adjacent organs can adhere to the involved serosa overlying a gastric cancer. This may be followed by direct tumour invasion. General peritoneal contamination will have been minimised by the malignant adhesions, but the prognosis is still poor. Extended excisions to include other organs invaded by the primary tumour are seldom justified.

D2 subtotal gastrectomy

Subtotal gastrectomy with a D2 lymphadenectomy is particularly suitable for small gastric tumours involving the pylorus and distal third of the stomach. When macroscopic and microscopic clearance is obtained, it provides equivalent survival rates to total gastrectomy, with a lower incidence of postoperative morbidity and mortality. The patient is left with a gastric remnant, which in theory reduces the potential for post-gastrectomy syndromes. Additionally, an anastomosis onto a well-vascularised stomach remnant is more secure than an anastomosis onto the oesophagus.

Operative access is obtained via an upper midline or bilateral subcostal 'rooftop' incision. A thorough abdominal examination is performed to determine the presence of metastatic disease, which may not have been identified with staging. Up to 20% of gastric tumours are understaged in the preoperative assessment. Peritoneal deposits, liver metastases or the presence of metastatic disease in para-aortic lymph nodes precludes curative resection. A frozen-section examination may help differentiate metastatic disease from inflammatory reaction when enlarged nodes are encountered. If a curative procedure is not possible, the surgeon may still elect to proceed with a palliative resection for control of bleeding or the relief of outlet obstruction, in which case the retrieval of lymph nodes is of much less importance.

The first steps are to mobilise the splenic and hepatic colonic flexures and to Kocherise the duodenum.[29] The greater omentum is detached from the transverse colon but in such a way as to enter the plane deep to the anterior leaf of the transverse mesocolon (Figure 9.7). The dissection continues in this plane, avoiding damage to the middle colic vessels or their branches. Classically, the omentum and the anterior leaf of the transverse mesocolon are removed *en bloc* with the stomach, thus keeping the lesser sac unopened at this stage. The dissection is continued on the right side until the right gastroepiploic vessels



9.7 Sagittal section showing the classical plane of dissection, including bursectomy and omentectomy, deep to the anterior layer of the transverse mesocolon and deep to the peritoneum of the posterior wall of the lesser sac. ⏎

and subpyloric lymph nodes are identified. The right gastroepiploic vessels are carefully ligated and divided at their origins, and the nodes swept up into the tissue to be excised. The dissection is carried onto the pancreas, taking the overlying peritoneum/pancreatic capsule with the specimen. It is imperative to be in the correct plane. This plane on the surface of the pancreas is then followed laterally, where it will allow access to the left gastroepiploic and short gastric vessels. The left gastroepiploic vessels are divided, but the short gastrics must be carefully preserved as the only blood supply of the gastric remnant.

The omentum is then returned to the abdomen and the liver elevated with a retractor to expose the gastrohepatic ligament. This is divided at its left extremity to provide access to the oesophageal hiatus. The division of the peritoneal reflection onto the liver is then continued to the right and the lesser sac is entered. In an antral carcinoma, consideration should be given as to whether portal dissection, with retrieval of station-12 lymph nodes, is indicated. When some selective additional third-tier nodes are removed, the operation may be referred to as a D2/3 gastrectomy. If these nodes are not to be dissected, the incision across the peritoneal reflection onto the liver stops to the left of the common bile duct and turns inferiorly towards the duodenum. When station-12 nodes are to be retrieved, the hepatoduodenal ligament is opened by continuation of the peritoneal incision into Calot's triangle, providing exposure of the common bile duct, hepatic artery and portal vein. The hepatic artery and its bifurcation are skeletonised, with retrieval of all lymph-bearing tissue. A tape around the hepatic artery, with slight traction, will provide exposure to the anterior portion of the portal vein. This dissection should yield a significant number of lymph nodes, which are excised in continuity with the main specimen. Whether the portal nodes are retrieved or not, the line of dissection comes down onto the common hepatic artery. The right gastric artery arising from the common hepatic artery is identified and ligated near its origin.

The duodenum must be fully Kocherised to allow access to the retropancreatic and hepatoduodenal regions. This exposes the inferior vena cava and abdominal aorta, and also allows retrieval of right para-aortic and retropancreatic lymph nodes. The duodenum is then divided and closed. This is most easily achieved with a linear cutting stapling device but, alternatively, it can be divided between two non-crushing clamps and the distal limb closed using a continuous 3/0 absorbable suture. Duodenal division provides access to the infrapyloric group of lymph nodes. Elevation and cephalad traction on the stomach expose the coeliac axis and the left gastric artery, along with the lymph nodes associated with these vessels. The left gastric artery is divided near its origin, with division of the left gastric vein along the superior border of the pancreas. Retrieval of tissue surrounding the left gastric artery, the hepatic artery and the coeliac trunk provides a high yield of lymph nodes. The ascending branch of the left gastric is divided just above the GOJ so that the whole lesser curve arterial arcade and lymph nodes can be removed (see Figure 9.2). Stay sutures are placed at the greater and lesser curves and the stomach is transected, leaving a small gastric remnant with a blood supply from the remaining short gastric vessels. Once resection and lymphadenectomy are complete, reconstruction can be performed by a Billroth II or Roux loop technique. Surprisingly, a Billroth I reconstruction may also be an option after the extensive mobilisation that has been needed for the radical lymphadenectomy.

Total D2 gastrectomy with Roux-en-Y reconstruction

When potentially curative surgery is undertaken, it is essential that the intramural spread of gastric cancer is remembered. Therefore, except in early gastric cancer, a total gastrectomy becomes necessary for all but antral tumours. Radical lymphadenectomy is of great importance, but is often not an exact D2 dissection in that, depending on the location of the tumour, some second-tier nodes may be left *in situ* and some third-tier nodes removed.

For a total gastrectomy, superior access will be required to the oesophageal hiatus and additional transhiatal dissection may be necessary for a proximal tumour. Goligher-type retractors or an Omni-Tract system are helpful, but a left thoracoabdominal incision may have to be considered for an extensive tumour involving the GOJ. The initial assessment and dissection then follow the same principles as those for a subtotal D2 gastrectomy, as described above, until the dissection on the surface of the pancreas approaches the splenic hilum. Here, all of the short gastric vessels are divided in addition to the left gastroepiploic vessels.

The dissection then continues in a similar fashion to that described for the radical subtotal operation in order to retrieve lymph nodes associated with the gastric arcade, the hilum of the liver and the origins of the right gastric and gastroepiploic vessels. The dissection then returns to the greater curve, and the remaining short gastric vessels are divided as close to the splenic hilum as is safe and the lymph nodes taken *en bloc*. It is sometimes justifiable to include the spleen and even the pancreatic tail *en bloc* in the resected specimen, in which case the dissection proceeds lateral to the spleen to mobilise the spleen completely. The splenic vessels, rather than the short gastric arteries, must then be ligated. When the stomach is fully mobilised and any remaining adhesions divided, stay sutures are inserted into the distal oesophagus to prevent oesophageal retraction after the stomach has been removed. It may be possible to apply a non-crushing clamp proximal to the oesophageal stay sutures. The oesophagus is then divided using either a scalpel or straight scissors. When the gastrectomy is for a cancer close to the cardia, it is desirable to include at least a short segment of oesophagus in the resected specimen, along with a cuff of diaphragm. When a longer segment of oesophagus needs to be resected, a thoracoabdominal approach or some other, more formal, access into the left chest is preferable.

A Roux-en-Y loop is brought up for reconstruction and the formation of an end-to-side oesophagojejunal anastomosis is recommended. An oesophagojejunal anastomosis is formed using a single layer of absorbable monofilament sutures inserted in an interrupted fashion, but it can also be performed using a circular stapler. The head is carefully inserted into the oesophageal lumen, where it is secured with a purse-string suture. The main portion of the stapler is then inserted, via an enterotomy, into the jejunum. The enterotomy is subsequently closed using a hand-sewn technique. There is also the option of using a longer segment of jejunum for the Roux loop and making the end into a jejunal pouch using the linear stapler. This may improve the patient's postoperative capacity for food; evidence is mixed and, as such, it is seldom performed in Western practice.[30]

Laparoscopic or robotic D2 gastrectomy

Minimally invasive (laparoscopic or robotic) D2 gastrectomy is highly specialised and concentrated in a few units. An advanced level of laparoscopic skill and technique proficiency is required for the dissection and, again, any oncological compromise will negate any short-term benefits of avoiding an open operation. Although initially pioneered in Asia, good results are now being obtained in the West in terms of node harvest. However, the laparoscopic technique has less emphasis on the *en bloc* resection of the tissue, the lesser sac is often entered early and the upper leaf of the transverse mesocolon left *in situ*. There are, therefore, theoretical disadvantages, namely lymphatic channels may be transgressed with resultant peritoneal contamination. However, as long-term results have not so far shown a worse prognosis, a laparoscopic approach has been accepted as an alternative operative strategy.[5]

PALLIATIVE SURGERY

The survival of patients in whom a curative resection is not possible is poor and, in general, palliative surgery has a limited role. Chemotherapy can achieve a remission, with a reasonable quality of life, for a minority of patients.

If, during the laparotomy, operative findings are discovered that preclude a curative resection, the surgeon must decide whether a palliative resection, a bypass or no further surgical procedure will offer the patient the best quality of life. This is a decision that, prior to advances in preoperative staging, had to be made frequently, and it may still be a common problem for surgeons with limited access to sophisticated imaging modalities. The surgeon must be careful not to be influenced by the understandable desire 'to do something' and the perception of failure if an 'open and close' laparotomy is chosen. The decision is not always straightforward.

Palliative resection

This can offer the best palliation for a bleeding tumour, for gastric outflow obstruction and for the non-specific, but distressing and unpleasant, symptoms associated with a fungating intragastric mass. It should certainly be considered for a small mobile distal tumour in a fit patient with a small metastatic load, especially as a palliative partial gastrectomy for malignancy does not need to include a radical lymphadenectomy. It should be remembered that, if there is a heavy metastatic load, the mortality and morbidity of any major resection will be significantly increased. No anastomosis should be attempted through macroscopically malignant tissue and, if the tumour cannot be cleared with a partial gastrectomy, a total gastrectomy is seldom justified, as the quality of life with a total gastrectomy and metastatic malignancy is extremely poor.

Bypass procedures

A gastroenterostomy can offer good palliation when an unresectable distal growth is causing a gastric outflow obstruction. This is often undertaken electively in patients whose cancers are known to be too advanced for curative surgery, but who have developed obstructive symptoms. However, the alternative of an endoscopic pyloric stent should always be considered. When the abdomen has already been opened and an unresectable tumour confined to the distal stomach is encountered, a gastroenterostomy is often justified, even in the absence of an established outlet obstruction, as there is a high risk of obstruction developing as the cancer advances. It is important to fashion the gastroenterostomy to a dependent part of the stomach, but as far from the tumour as possible to avoid later tumour obstruction of the anastomosis. A thorough abdominal examination should also be undertaken to determine the presence of peritoneal seedlings, which might cause a future small bowel obstruction. This complication may sometimes be avoided if a stenosing serosal secondary is removed as a wedge excision.

Proximal tumours can cause dysphagia, and they frequently present when they are locally irresectable or the patient already has metastatic spread. Palliative surgical bypass is seldom a practical option, but fortunately these cancers can usually be stented endoscopically with relief of distressing symptoms.

PROPHYLACTIC SURGERY IN HEREDITARY DIFFUSE GASTRIC CANCER

The presence of familial clusters of gastric cancer following an autosomal dominant pattern has been observed for many years. Surveillance has been unsuccessful, mainly because of the diffuse, submucosal nature of the cancer, which makes it undetectable despite repeated endoscopies. Most patients, even when under surveillance, present at an advanced stage with unresectable disease. The penetrance rate of the gene is reported at 70–80% and, in the absence to date of a successful surveillance mechanism, a prophylactic total gastrectomy with Roux-en-Y reconstruction is a viable therapeutic option. However, the mortality and morbidity risk is not insignificant and genetic counselling in high-risk families is essential before offering any genetic testing.

When performing a total prophylactic gastrectomy for hereditary diffuse gastric cancer, it is imperative that all gastric mucosa is removed and that the transection is above the GOJ and incorporates oesophageal squamous mucosa. This is confirmed intraoperatively by the pathologist with frozen-section examination. Any gastric mucosa left behind places the patient at a significant risk of cancer in the remnant tissue. Radical lymphadenectomy, which is usually associated with a total gastrectomy, is not required.

OTHER GASTRIC MALIGNANCIES

GASTROINTESTINAL STROMAL TUMOURS

GISTs are mesenchymal tumours of variable malignant potential and are most commonly encountered in the stomach. They were previously considered to be gastric leiomyomas or leiomyosarcomas. Although the tumour behaviour can be partially predicted histologically, this information is seldom available to the surgeon preoperatively. In general, a small tumour discovered as an incidental finding behaves in a benign fashion and the larger tumours, which present symptomatically, are usually more aggressive. Some patients present at an advanced stage with extensive disease, and there may also be peritoneal and liver metastases.

Despite investigations, it is often not possible to establish the diagnosis preoperatively, especially as, if a curative resection is planned, it is important to avoid biopsy with the risk of spillage of tumour cells. A common presentation of a GIST is as an emergency with haemorrhage and the bleeding is seen at endoscopy to be from an ulcer on the summit of a submucosal gastric mass. Complete surgical clearance with negative margins is the main treatment objective. In smaller lesions, this can be achieved through wedge or partial resection. In large lesions, achieving a full resection may require the removal of adjacent organs.

OPERATIVE MANAGEMENT OF COMPLICATIONS OF UPPER GASTROINTESTINAL SURGERY

HAEMORRHAGE

Early postoperative haemorrhage

A major intraperitoneal bleed may result from an unrecognised splenic injury or a ligature that has slipped from a gastric vessel. Laparotomy for control of haemorrhage is indicated. Mediastinal bleeding may be from the azygos vein or from oesophageal branches of the aorta; while rare, these can be fatal if not rapidly recognised. Even when the original oesophageal dissection has been performed transhiatally, access to deal with this emergency will require a thoracotomy.

Intraluminal haemorrhage after a gastric resection or anastomosis is usually due to bleeding from a suture line. The patient may have melaena or have fresh blood in the nasogastric tube. Most bleeding is self-limiting and settles spontaneously, but if the bleeding is excessive or persists, then an endoscopy should be performed. Minimal insufflation is used and diathermy should be avoided if the primary anastomosis was formed using staples. If endoscopic control of significant bleeding is unsuccessful, then re-operation is mandatory. Anastomotic bleeding can be controlled by oversewing the staple line with sutures.

Secondary haemorrhage

This usually occurs around 2 weeks after surgery and is associated with intra-abdominal sepsis. The tissue is friable and any bleeding vessel is difficult to secure. Interventional radiology and embolisation may be a better solution than surgery. However, the haemorrhage may be sudden and torrential, and immediate laparotomy may then be the only option. A supracoeliac aortic clamp will sometimes provide temporary control in this situation. Delayed mediastinal bleeding is rare but usually associated with anastomotic leakage and fistulation into a blood vessel. Again, the nature of delayed presentation and sudden blood vessel failure means that this is often a fatal occurrence if not immediately recognised and controlled.

ANASTOMOTIC FAILURE

Anastomotic failure presents as a wide range of clinical scenarios. At one end of the spectrum is a patient who is clinically well but has a subclinical leak with radiological evidence of extravasation of contrast. At the other end of the spectrum is a patient who is profoundly unwell and in whom the gastric remnant or the oesophageal conduit that has been used for the anastomosis has necrosed.

Ischaemic necrosis of the gastric remnant or conduit

Proximal gastric remnant This serious complication of a distal gastric resection is fortunately uncommon. Predisposing factors include ligation of the left gastric artery, combined with excessive mobilisation of the greater curve with compromise of the blood supply from the short gastric vessels, particularly in association with a splenectomy. If the entire remnant has necrosed, then a completion gastrectomy with a Roux-en-Y reconstruction will be required. If the ischaemia extends to the distal oesophagus, then a primary anastomosis is problematic. A cervical oesophagostomy is performed, with colonic or jejunal interposition reconstruction at a later stage.

Gastric, colonic or jejunal conduit The blood supply of the gastric conduit, which has been mobilised to bring it up for an anastomosis to the proximal oesophagus, is vulnerable, as it depends solely on the right gastroepiploic artery. Alternative oesophageal conduits are similarly vulnerable in that they depend on single vessels, of variable size and anatomy, to perfuse the entire length of the conduit. The most vulnerable area, that of the anastomosis, is invariably also the area that is furthest away and least well perfused. Postoperative ischaemic necrosis of a conduit is associated with high mortality, not least because surgical intervention in the form of a thoracotomy is usually necessary. The necrotic part of the conduit is resected and the viable portion closed and returned intra-abdominally. A cervical oesophagostomy is then performed with future reconstruction with alternative conduit possible if the patient survives and does not suffer cancer recurrence.

Anastomotic dehiscence

The presentation of anastomotic dehiscence is variable. Patients may have systemic sepsis from thoracic or peritoneal soiling, or a minor leak may only be demonstrated on contrast imaging. An anastomotic leak in the neck will usually present with localised sepsis or the development of a fistula. Subclinical leaks will usually settle if commencement of oral intake is postponed. Generalised peritonitis or mediastinitis will require re-operation, but with the advancement of techniques the vast majority of localised abdominal and thoracic abscesses secondary to minor anastomotic leaks can be successfully managed with antibiotics and non-surgical drainage.

Patients who are clinically well without systemic sepsis may be managed with antibiotics alone, avoidance of oral intake to prevent further mediastinal soiling and appropriate nutrition via an alternative route. For patients who demonstrate signs of sepsis but without systemic decompensation, negative pressure therapy is being increasingly used to treat such (type II) anastomotic leaks. Under general anaesthetic, a sponge connected to a nasogastric tube is placed into the cavity or defect and connected to a negative pressure device at 50–75 mmHg (https://evt-academy.com). Alternatively, a nasogastric tube alone may be placed into the defect and placed on negative pressure. Negative pressure sponges are thought to accelerate granulation and healing, but have the drawback of requiring regular changes under anaesthetic, every 3–4 days. In small defects without large mediastinal collections, a covered stent can also be considered.

In patients with large extraluminal collections, or systemic compromise, re-operation should not be delayed. Washout and placement of peri-anastomotic drainage will allow formation of a controlled fistula until sepsis is controlled and healing begins. Re-suturing a leaking anastomosis in the presence of contamination is not recommended.

Duodenal stump blowout

Duodenal stump blowout is a life-threatening complication that may occur following any procedure that involves division and closure of the duodenum, as in a Billroth II or a total gastrectomy. An ultrasound scan may identify a fluid collection in the region of the duodenal stump, and aspiration of the collection confirms bile. Small collections may be managed by percutaneous radiological drainage in combination with broad-spectrum antibiotics and parenteral nutrition.

If radiological drainage is unavailable or is unsuccessful, then surgery is necessary. Unfortunately, on re-entering the abdomen, there is often considerable inflammation and sepsis with anatomical distortion. Primary closure is not safe in this hostile environment. Instead, a controlled fistula should be created. A distal feeding tube to enable enteral nutrition is important for postoperative recovery. While some clinicians may advocate for octreotide to reduce the fistulous output, there is little evidence that this has any effect on clinical outcomes. An adequately drained controlled duodenal fistula will usually heal unless there is local infection, mechanical obstruction of the afferent limb, associated pancreatitis or a persistent duodenal ulcer.

ACUTE GASTROPARESIS

Many patients, following upper gastrointestinal tract surgery, have a degree of gastric atony that generally recovers within 10–12 days. Delayed gastric emptying may also occur secondary to anastomotic site oedema. Conservative management consists of nasogastric tube insertion to decompress the stomach, correction of electrolyte imbalances, maintenance of nutrition and the use of prokinetics, such as erythromycin. Persistent symptoms for more than 4 weeks should raise the possibility of an underlying mechanical problem, which may need surgical intervention.

CHYLOUS LEAK

Chylothorax is a collection of chyle within the mediastinum or pleural cavity. It occurs following damage to the thoracic duct or right broncho-mediastinal trunk. Often there is a delay of up to 10 days between the time of injury and the onset of symptoms. Persistent output from the chest drain following an oesophagectomy or the development of a pleural effusion, usually on the right, should arouse suspicion. Biochemical analysis of the pleural aspirate will confirm a high triglyceride and chylomicron content. Chylothorax carries a mortality rate of 30% and must be actively managed.

Conservative management

Conservative management, which includes total parenteral or fat-free/medium-chain triglyceride-based enteral nutrition to reduce chylous output, has a success rate of approximately 50%. High-volume iatrogenic chylothorax – defined as over 1 L of chyle produced each day for 4–6 days – is most unlikely to respond to conservative management, and the patient becomes progressively metabolically and nutritionally compromised. Early surgery is therefore recommended for these high-volume leaks. A smaller-volume leak that has persisted for over 2 weeks is another indication to consider surgical intervention.

Surgical intervention

At re-exploration, there are two main choices. The thoracic duct can be ligated just above the diaphragm or, alternatively, the laceration can be localised and repaired. Preoperative administration of cream via the nasogastric or feeding jejunostomy tube will increase the production of chyle and may help in identification of the injured duct. The use of methylene blue dye is not recommended because of tissue staining, which interferes with visualisation. Indocyanine green (ICG) can be used to great effect by injecting either into groin lymphatic nodes or into small bowel mesentery. Within a short interval (20 minutes), ICG can be visualised with a suitable infrared visualisation system – increasingly included as part of current generation laparoscopic and robotic platforms – to directly identify the site of leakage for surgical ligation.

Some centres recommend that, if surgical intervention for a persistent chylous leak is required, the transabdominal approach is better.[14]

Radiological intervention

A suitably trained and experienced interventional radiologist may also attempt to directly cannulate the lymphatic system and directly embolise the thoracic duct or site of leakage.

LATE COMPLICATIONS OF GASTRIC SURGERY

Adhesion obstruction can follow any intra-abdominal surgery, but intestinal obstruction from internal hernias can be difficult to diagnose, especially after some of the more complex operations for morbid obesity. Routine endoscopic access to upper gastrointestinal haemorrhage or common bile duct stones may also be no longer possible.[30] Both resectional and non-resectional gastric surgery create permanent changes in gastrointestinal function. Some of the adverse consequences of these changes can be modified by further surgical intervention.

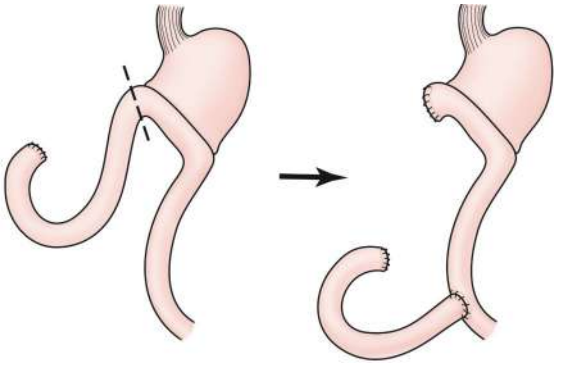
Alkaline reflux gastritis

Reflux of alkaline intestinal contents, particularly bile, into the stomach causes mucosal damage. Enterogastric reflux is most common after a Billroth II gastrectomy or a gastroenterostomy. Further reflux into the oesophagus can then cause an alkaline oesophagitis. Conservative management, including the use of bile-sequestering agents, provides little symptomatic relief, but further surgery can be very effective.

In patients who have had a truncal vagotomy with gastroenterostomy, the simplest solution is to take down the gastroenterostomy. Gastric stasis is seldom a problem if more than a year has elapsed since the initial surgery, as poor post-vagotomy gastric tone improves with time, but there is a risk of recurrent duodenal ulceration if the original vagotomy was incomplete. Reversal of the gastroenterostomy is contraindicated if there is any stenosis of the pylorus. Instead, an antrectomy with a Roux loop reconstruction should be considered.

After a Billroth II gastrectomy, alkaline reflux oesophagitis can be relatively simply treated by the conversion of the gastric drainage to a Roux-en-Y gastrojejunostomy (Figure 9.8). The Roux limb directs the alkaline contents 45–60 cm beyond the gastric remnant, thereby reducing the potential for bile reflux. However, this is what is called an 'ulcerogenic manoeuvre', as it diverts the buffering effect of the alkaline gastrointestinal secretions from the gastroenteric anastomosis. This is an important consideration if no vagotomy was performed and the gastrectomy was relatively conservative, with retention of much of the parietal cell mass. The addition of a vagotomy should therefore be considered, especially if the original operation was for peptic ulceration.

Enterogastric reflux can also occur in a retrograde fashion when the pyloric sphincter has been destroyed by a pyloroplasty or has been excised and continuity restored by a Billroth I anastomosis. Reversal of a pyloroplasty is relatively straightforward and may be successful. The time that has elapsed since the surgery must again be considered. If the pylorus is too scarred to be reconstructed, an antrectomy with a Roux loop reconstruction is again the favoured option if the original operation was a vagotomy and pyloroplasty. When the previous surgery was a Billroth I gastrectomy, this can be revised to a Roux loop anastomosis. The loss of buffering alkali to this anastomosis must again be considered. One manoeuvre for achieving Roux loop drainage without taking down the original anastomosis is with the DeMeester duodenal switch procedure, which is illustrated in Figure 9.9. This can also be a useful operation for alkaline reflux gastritis and oesophagitis, which can be particularly troublesome after an oesophagectomy that was combined with a proximal partial gastrectomy.



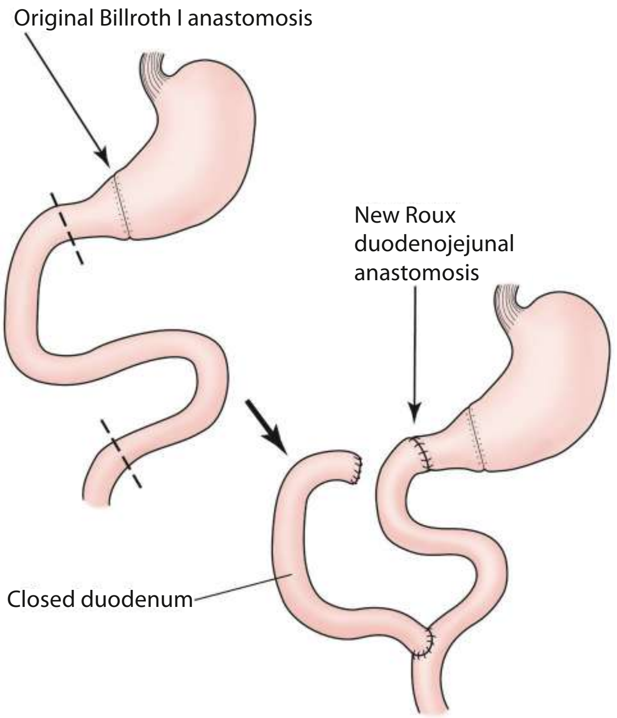
9.8 A Billroth II (Polya) anastomosis can be easily converted to a Roux loop. ⏎

Interposition of an isolated isoperistaltic jejunal loop as a spacer between the gastric remnant and duodenal stump has also been used to reduce bile reflux after a Billroth I gastrectomy.

Dumping syndrome

This is one of the most common complications of gastric surgery and is partly the result of the lack of an effective pyloric sphincter to control delivery of a glucose-rich meal into the small intestine. However, the coeliac branch of the vagus nerve has also been implicated and its preservation has been shown to reduce dumping.[15]

Early dumping occurs within a few minutes of the meal, as the hyperosmolar intestinal contents cause significant fluid shifts into the intestinal lumen. This results in epigastric pain and explosive diarrhoea in association with systemic vasomotor symptoms secondary to the hypovolaemia.


Original Billroth I anastomosis
New Roux duodenojejunal anastomosis
Closed duodenum

9.9 DeMeester duodenal switch operation after a previous Billroth I gastrectomy. ⏎

Late dumping occurs several hours after a meal. The large glucose load presented to the small intestine causes hyperglycaemia, followed by a compensatory hyperinsulinaemia, which then results in later hypoglycaemia and associated systemic symptoms.

The majority of these patients respond to dietary manipulation consisting of small-volume, frequent meals that are low in refined carbohydrate. Octreotide, when taken preprandially, is associated with a significant improvement in vasomotor and gastrointestinal symptoms. If symptoms persist, surgical intervention should be considered to slow the delivery of gastric contents into the bowel. The reconstruction of a pylorus after a pyloroplasty or the dismemberment of a gastroenterostomy as described above can be successful. The conversion from a Billroth I or Billroth II reconstruction to a Roux-en-Y loop may be effective, as it slows the delivery of gastric contents into the small bowel.

Afferent and efferent loop syndromes

Afferent and efferent loop syndromes occur secondary to partial or complete loop obstruction.

Afferent loop syndrome may present acutely early in the postoperative period following a Billroth II gastrectomy or a Roux loop reconstruction and is a surgical emergency. The closed loop is at imminent risk of perforation, usually as a duodenal stump blowout. There may be an associated rise in serum amylase levels, giving rise to a misdiagnosis of acute pancreatitis. A subacute or chronic presentation, with non-specific symptoms, is more common. Again, pancreatitis may be suspected until imaging demonstrates a dilated pancreaticobiliary afferent limb. Surgical options after Billroth II gastrectomy include conversion to a Billroth I or to a Roux-en-Y reconstruction. When the original reconstruction was with a Roux loop and the pancreaticobiliary segment is obstructed by a stenosis of the jejunojejunal anastomosis, this can simply be re-fashioned.

Efferent loop syndrome is much less common and usually occurs secondary to adhesions, internal herniation or jejunogastric intussusception. Patients present with symptoms of a proximal small bowel obstruction. Surgical intervention is indicated.

Stomal ulceration

Stomal ulceration is most frequently seen after surgery for peptic ulcer disease. The ulcer occurs where the jejunum has been anastomosed to the stomach and exposed to gastric acid. A gastroenterostomy is thus prone to stomal ulceration if a vagotomy has not been performed, and a Roux loop drainage is even more vulnerable as the buffering effects of alkaline intestinal secretions at the anastomosis are absent. Therefore, a Roux loop should ideally be used only in combination with a vagotomy or when there is a small gastric remnant with less acid-producing potential. Management of recurrent and stomal ulceration is initially conservative and consists of proton-pump inhibition, eradication of *Helicobacter pylori* and avoidance of aggravating factors. If ulcers are refractory to medical management, the surgical options depend on the previous surgery. Completion vagotomy, combined with antrectomy, is often the best option.

In both stomal and recurrent ulceration, an underlying malignancy and also underlying pathologies, such as Zollinger–Ellison syndrome, must be excluded.

Anastomotic stricturing

Anastomotic strictures may develop any time in the postoperative period but are most commonly observed in the initial months postoperatively. The usage of circular stapled anastomoses, particularly if using smaller diameter devices, and resolved anastomotic leak are particular risk factors for strictures, but strictures may occur in any anastomosis. Repeated balloon or bougie dilatation is required until a stable patent anastomosis can be achieved. In recalcitrant strictures, steroid (triamcinolone) injections may be considered as an adjunct.

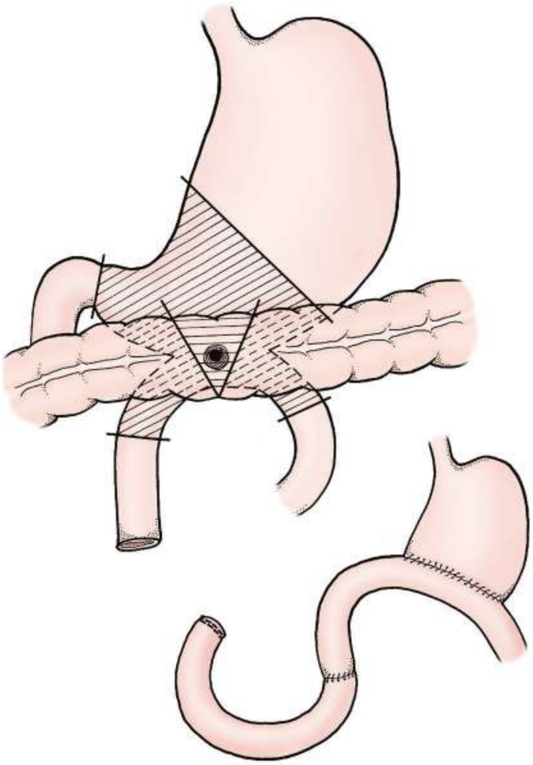
Delayed gastric emptying

Delayed emptying of the denervated gastric conduit after oesophagectomy is not uncommon. Patients may present with symptoms of early satiety, reflux or regurgitation. Initial investigation with oesophagogastro-duodenoscopy is typical but, if diagnostic uncertainty exists, a contrast swallow/meal may also be considered to confirm the diagnosis and delayed transit through the pylorus.

Delayed gastric emptying is treated in the first instance with balloon dilatation of the pylorus. Botulinum toxin injection into the pylorus may also be used as an adjunct. If symptoms recur repeatedly and endoscopic pyloric interventions successfully improve them, formal surgical pyloromyotomy may be considered.

Gastrojejunocolic fistula

A gastrojejunocolic fistula is a fistula between a gastroenterostomy and the transverse colon (Figure 9.10). This was once a well-recognised complication of a long-standing stomal ulcer, but is now very rare in the developed world. Patients present with intractable diarrhoea from bacterial contamination of the small bowel, giving rise to severe nutritional deficiencies



9.10 Resection for a gastrojejunocolic fistula. ⏎

and weight loss. The situation is best managed by antrectomy, removal of the involved colonic segment followed by a gastroduodenal or gastrojejunal anastomosis and primary colonic anastomosis. In severely ill patients, this may have to be a staged procedure.

A gastrocolic fistula can also occur secondary to a gastric or colonic neoplasm or as a complication of gastric surgery.

Hiatal herniation

Division of the phreno-oesophageal ligament and disruption of the pleura during oesophagectomy, and not uncommonly during gastrectomy, creates potential space for herniation of viscera through the oesophageal hiatus. Whether picked up incidentally on imaging or through acute presentation, surgical repair should be pursued to prevent hernia extension, incarceration or strangulation. Worse still, incarceration of hernia contents alongside the gastric conduit has the potential to also threaten blood supply to the conduit.

These are challenging problems with high recurrence rates. Typically, the herniated viscera, lacking a true hernia sac, may be easily reduced. Extreme care must be taken to avoid damaging the conduit and its blood supply. Suture cruroplasty, cruropexy to the conduit or colopexy to the anterior abdominal wall may reduce the risk of further herniation; recurrences are common.

Tracheo-oesophageal fistulae in oesophageal cancer

An acquired tracheo-oesophageal fistula is almost always secondary to direct invasion by a primary or secondary tumour or it occurs as a complication of the treatment of a malignancy, which is most often an oesophageal tumour. The fistula may arise spontaneously with tumour advancement or it may occur following oesophageal surgery or radiotherapy. The patient presents with extreme respiratory compromise and recurrent pulmonary infections and, despite aggressive intervention, the condition is often fatal. The diagnosis can be confirmed by instillation of a water-soluble contrast medium into the oesophagus. The fistula may also be visualised by endoscopy or bronchoscopy, which helps to determine if there is a malignant cause for the communication. Acquired tracheo-oesophageal fistulae will not close spontaneously and require operative intervention if the patient is stable. In critically ill patients, oesophageal ligation, with the creation of a high oesophagostomy and a gastrostomy, may offer the best outcome. If the fistulation is due to a primary or secondary malignancy, management is principally palliative and aimed at symptomatic relief.

Aggressive operative intervention should be considered in patients who have a fistula as a complication of oesophagectomy performed for an early cancer and also in those who have had a complete pathological response following radiotherapy. High fistulae may be approached via a low collar incision. Fistulae at the level of the carina require a lateral thoracotomy for access. If the fistula is small, it may be divided and the oesophagus and trachea closed primarily. In the neck, the strap muscles are mobilised and placed between the oesophagus and trachea to buttress the closure, thus reducing the potential for breakdown and recurrence. In the thorax, the closure can be protected with a pleural and intercostal muscle flap. Alternate muscle flaps including latissimus dorsi flaps may also be utilised. Large fistulae may require tracheal resection and reconstruction. When a tracheo-oesophageal fistula occurs as a complication of oesophagectomy, the gastric tube may have to be removed and an interposition graft, using colon or jejunum, fashioned. Bronchial stents may also be of benefit in certain circumstances.

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10 Gallbladder and biliary surgery

Anand Bharathan and Jayapal Rajendran

ANATOMY

GALLBLADDER

The gallbladder is pear shaped and about 10 cm in length. It is attached to the inferior surface of the right lobe of the liver and is enclosed within a peritoneal sheath. The extent of this attachment varies from a gallbladder that is deeply embedded within the liver to one that is suspended on a mesentery. The interface between the gallbladder and liver is a relatively avascular, loose areolar plane called the cystic plate. Commonly, the lower end, or fundus, of the gallbladder is completely covered with peritoneum and projects slightly beyond the free margin of the liver. The body and neck are usually covered on three sides by peritoneum, the gallbladder being attached anteriorly to the liver by loose connective tissue and easily separated from the liver. The neck narrows down to form the cystic duct. If a gallstone becomes lodged in the neck of the gallbladder, it creates a dilatation at this point, known as Hartmann's pouch. The cystic duct, which is of variable length and width, runs backwards, and medially, and joins the common hepatic duct (CHD) to form the common bile duct (CBD). The mucosa of the cystic duct is arranged in spiral folds, the valves of Heister. The gallbladder is supplied by the cystic artery, which is usually a branch of the right hepatic artery, although this is variable.

BILE DUCTS

The right and left hepatic ducts emerge from the liver through the porta hepatis and unite to form the CHD, which is in turn joined by the cystic duct to form the CBD. The CBD is about 10 cm long and up to 7–8 mm in diameter. It runs down behind the first part of the duodenum, then either lies in a groove in the posterior aspect of the head of the pancreas or tunnels through the pancreatic gland substance and ends by passing obliquely through the posteromedial wall of the second part of the duodenum. The extreme lower end of the duct is accompanied by the main pancreatic duct (of Wirsung), which runs parallel to the CBD and unites with it to form the ampulla of Vater, which opens into the duodenum at the summit of a papilla. The ends of each duct, and the ampulla, are surrounded by circular muscle fibres, forming the sphincter of Oddi. Phasic contractions of the sphincter allow bile flow into the duodenum and possibly prevent reflux of duodenal contents into the biliary and pancreatic ducts.

The hepatic ducts and the supraduodenal part of the CBD lie in the right free border of the hepatoduodenal ligament. The hepatic artery proper lies posteromedial to the CBD and the portal vein lies posterior to the CBD and artery. The right hepatic artery usually crosses posterior to the CHD, where it gives off the cystic artery (Figure 10.1).

Anomalies

The above description of the anatomical relationship between the bile ducts, and associated blood vessels, is the description given in standard textbooks of anatomy. It should be noted, however, that considerable variation may exist, and those variations that occur most commonly are shown in Figure 10.2. A knowledge of such 'anomalies' is of great importance to the surgeon, as failure to recognise variations at surgery may lead to complications. The severance of an anomalous, or accessory, hepatic duct would lead to a bile leak and consequent biliary peritonitis, while ligation of an abnormally placed right hepatic artery might produce hepatic infarction. Other anomalies render the right hepatic duct or CBD liable to injury.

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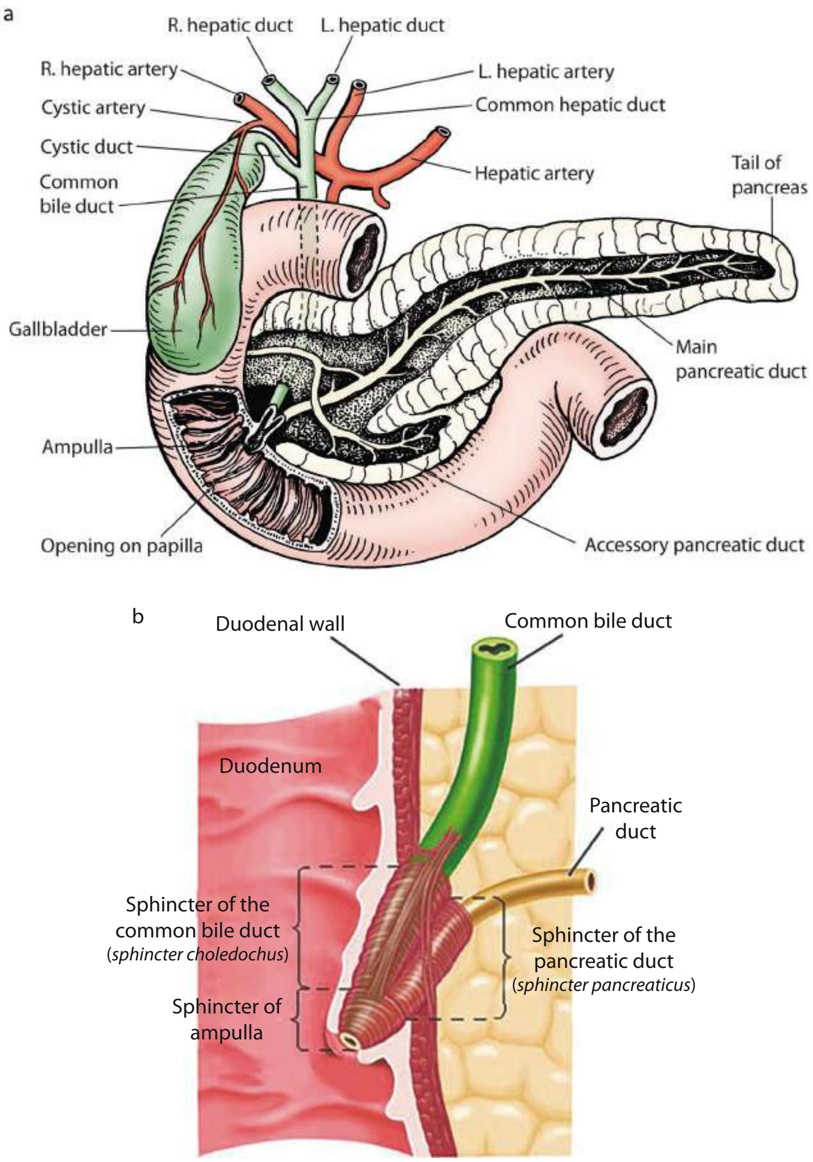
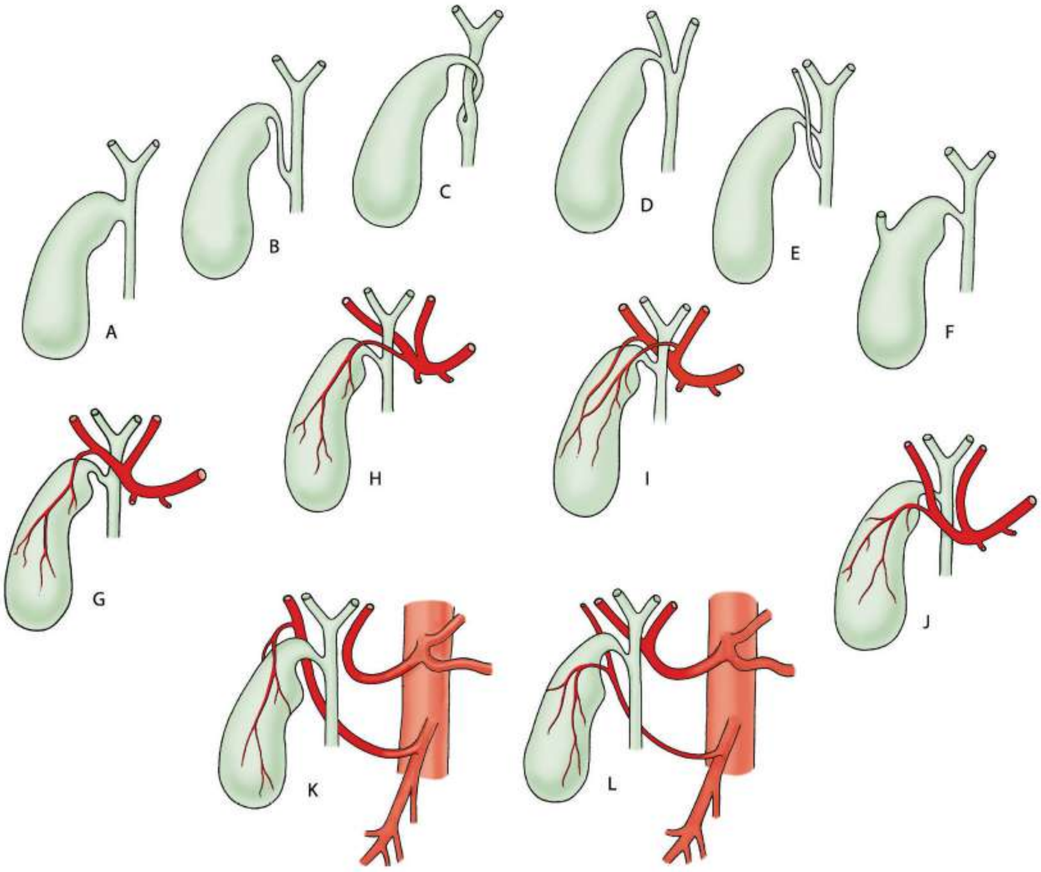

a
R. hepatic duct
L. hepatic duct
R. hepatic artery
L. hepatic artery
Cystic artery
Common hepatic duct
Cystic duct
Common bile duct
Hepatic artery
Tail of pancreas
Gallbladder
Main pancreatic duct
Ampulla
Opening on papilla
Accessory pancreatic duct
b
Duodenal wall
Common bile duct
Duodenum
Pancreatic duct
Sphincter of the common bile duct (*sphincter choledochus*)
Sphincter of the pancreatic duct (*sphincter pancreaticus*)
Sphincter of ampulla

10.1 (a) The relationship of the gallbladder and bile ducts to the duodenum and head of the pancreas. L, left. R, right. (b) Anatomy of the sphincter of Oddi. (b, From Aarons CB, Stucchi AF, Becker JM (2009). Biliary dyskinesia: functional gallbladder and sphincter of Oddi disorders. In: Bland KI et al. (eds) *General Surgery*. https://doi.org/10.1007/978-1-84628-833-3_108. Reproduced with permission of Springer Science+Business Media.) ⏎

GENERAL CONSIDERATIONS IN BILIARY SURGERY

BILIARY PHYSIOLOGY

About 0.5–1.5 L of bile is excreted through the ampulla of Vater every day, and most of the constituents are absorbed in the distal ileum. Hepatic bile is diverted into the gallbladder due to differential pressures within the biliary tree. Bile is concentrated within the gallbladder and intermittently expelled by spontaneous contractions or in response to cholecystokinin release, which occurs after eating. Cholecystokinin and glucagon relax the sphincter of Oddi to facilitate bile flow into the duodenum.



10.2 Anomalies of the bile ducts. A, short wide cystic duct; B, long cystic duct; C, long cystic duct winding round the hepatic duct; D, cystic duct joining the right hepatic duct; E, accessory hepatic duct joining the CBD; F, accessory hepatic duct draining into the gallbladder; G, right hepatic artery crossing in front of the CHD; H, cystic artery arising low and crossing in front of the CHD; I, accessory cystic artery from the left hepatic artery; J, low division of the hepatic artery; K, right hepatic artery arising from the superior mesenteric artery (SMA); L, accessory right hepatic artery arising from the SMA. ⏎

INVESTIGATION OF BILIARY DISEASE

Any operation on the biliary tract should be approached with the maximum possible information, and adequate time for investigation should be allowed. Liver function tests include serum bilirubin, liver enzymes (aspartate and alanine transaminase), biliary enzymes (alkaline phosphatase and gamma glutamyl transferase) and tests of synthetic function (albumin and prothrombin time). Appropriate imaging of the biliary tract may include transabdominal ultrasonography, magnetic resonance imaging (MRI) of the abdomen and magnetic resonance cholangiopancreatography (MRCP), abdominal computed tomography (CT) scan with vascular reconstruction, radionucleotide scans (hepatobiliary iminodiacetic acid [HIDA] scan), endoscopic or laparoscopic ultrasound, endoscopic retrograde cholangiopancreatography (ERCP) and percutaneous transhepatic cholangiography (PTC).

Interpretation of liver function tests in surgical practice

Obstructive jaundice is the most common biliary tract pathology seen in surgical practice. In obstructive jaundice, there is conjugated hyperbilirubinaemia and elevation of biliary enzymes. Elevation of transaminases usually indicates bacterial cholangitis. Synthetic function is variably affected. Prothrombin time is elevated in many patients and indicates easily correctable vitamin K deficiency, while low serum albumin is more common in a malignant aetiology where anorexia and cachexia are prominent features.

PREPARATION FOR BILIARY SURGERY

The general preoperative preparation and the intraoperative and postoperative management of patients are outlined in Chapter 3. Broad-spectrum antibiotics are recommended in emergency biliary surgery or if exploration of the CBD is anticipated. Deep vein thrombosis (DVT) prophylaxis is recommended, except when coagulation is impaired, when, instead, non-pharmacological prophylaxis using graded compression stockings and adequate hydration is crucial.

Additional preparation in the jaundiced patient

Both morbidity and mortality are higher following surgery in jaundiced patients, and patients must be meticulously optimised for surgery.[1]

Haemorrhage In obstructive jaundice, there is impaired absorption of fat-soluble vitamin K due to the failure of bile salts to reach the intestine. This results in a failure to synthesise clotting factors II, VII, IX and X and, in turn, coagulopathy, which may manifest as a prolonged prothrombin time. This is corrected by administering intravenous vitamin K (10 mg per day). Occasionally, the administration of blood products, such as fresh-frozen plasma, may be required during the perioperative period.

Infection The majority of patients with obstructive jaundice, and virtually all of those in whom the cause is gallstones, have infected bile. Jaundice also increases postoperative infective complications due to decreased Kupffer cell clearance, impaired cellular immunity and reticuloendothelial function, as well as reduced bile in the intestine leading to bacterial translocation. Broad-spectrum parenteral antibiotics (e.g. a second- or third-generation cephalosporin, or piperacillin and tazobactam) should be given on the induction of anaesthesia and continued postoperatively, depending on the operation and operative findings.

Renal failure Renal tubular function is compromised in jaundiced patients due to:

- The direct action of bilirubin on the tubules (bile cast nephropathy)
- Vascular shunting in the kidney leading to relative cortical ischaemia
- Hypovolaemia
- Hypotension due to biliary sepsis

Adequate preoperative hydration, appropriate and timely antibiotic cover, and close monitoring of urinary output are essential to minimise the risk of acute renal failure. Patients with hepatocellular jaundice may also develop renal failure in the absence of clinical, laboratory or other known causes of renal failure – *hepatorenal syndrome*. This poorly understood renal failure is unique to patients with hepatocellular jaundice due to decompensated liver cirrhosis and is a clinical diagnosis of exclusion, and improvement of renal function is dependent on recovery of liver function. Surgery for biliary pathology in patients with decompensated cirrhosis is generally futile and is best avoided, unless in the setting of liver transplantation.

BILIARY TRACT OPERATIONS

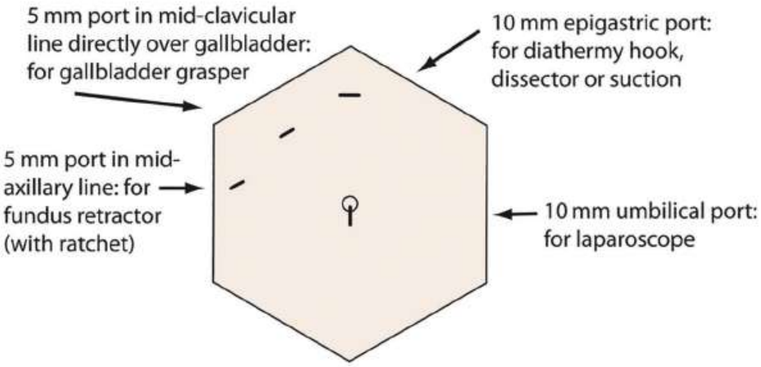
Position of the patient

The patient should be positioned supine on an operating table that allows radiographic screening for intraoperative cholangiography if required. Suitable laparoscopic port sites are shown in Figure 10.3, but further ports can be inserted as required to aid retraction or for the use of additional instruments.

Incisions and retractor systems for open procedures

The surgeon has a choice of several incisions, each of which allows good access to the biliary tree:

- *Reverse L-shaped incision*. This is the preferred incision of the authors for all major primary, and revision, biliary operations and for liver transplantation. The vertical component of the incision


5 mm port in mid-clavicular line directly over gallbladder: for gallbladder grasper
10 mm epigastric port: for diathermy hook, dissector or suction
5 mm port in mid-axillary line: for fundus retractor (with ratchet)
10 mm umbilical port: for laparoscope

10.3 Port sites for laparoscopic cholecystectomy. ⏎

starts at the level of the xiphisternum and extends to about an inch or two above the umbilicus. The horizontal component of the incision usually is made three finger breadths below the right costal margin, starting from the anterior axillary line, to meet the vertical component in the midline. Division of the falciform ligament and placement of fixed costal margin retractor systems, such as a Thompson or Omni-Tract retractor, with a Doyen blade to retract the liver, provides steady, wide exposure.

As a reverse L-shaped incision does not traverse along both subcostal margins, unlike a rooftop incision, postoperative pain is less than in the latter.

- *Bilateral subcostal/rooftop.* This conventional incision for major biliary operations also provides wide exposure at the cost of increased postoperative pain.
- *Kocher's subcostal.* This is the classic *oblique muscle-cutting* incision for an open cholecystectomy. It allows good access, especially in patients with a wide costal angle.
- *Right upper quadrant transverse.* This alternative to the Kocher incision provides a good cosmetic result and is often the incision of choice in neonates and infants.
- *Upper midline.* In patients with a narrow costal margin who are thinly built, an upper midline incision could provide adequate exposure to the biliary tree. This incision could be extended a few inches below the umbilicus, if required.
- *Mayo-Robson (hockey stick).* This is a combination of an upper midline and a medial subcostal incision.

Illumination

It is vital to have excellent illumination of the operative field during open biliary operations and the authors regularly use additional head-mounted lighting systems to provide steady lighting on the areas of dissection during complex biliary operations.

Preliminary exploration

The stomach and duodenum are examined first. The duodenum may be adherent to the gallbladder or to the porta hepatis area, and it is gently retracted down and the adhesions divided. In open operations, the stomach and duodenum are then packed off, out of the operative field. Laparoscopically, more use is made of gravity by placing the patient in a steep reverse Trendelenburg with a left-down tilt to keep the other abdominal viscera out of the operative field. Aspiration of a distended stomach by a nasogastric tube improves access. If the abdomen is open, the gallbladder is palpated for calculi, with particular attention being paid to the neck of the gallbladder, where a calculus may be overlooked, and the condition of the gallbladder wall is noted. In surgery for malignant disease, the entire abdomen must be carefully examined for evidence of tumour spread (nodal disease, liver metastases or peritoneal deposits).

SPECIFIC BILIARY SURGERY TECHNIQUES

Dissection

Even the simplest of biliary operations requires precise dissection in areas where there are important structures that must be preserved. Good access, illumination and assistance are all important. In the porta hepatis and hepatoduodenal ligament, the bile ducts, the hepatic artery and its branches, and the portal vein lie very close to each other within a peritoneal fold. The peritoneal covering of this biliovascular bundle needs sharp division before individually isolating these structures. The authors prefer to perform dissection of the covering peritoneal fold and tissues around these structures with judicious use of monopolar diathermy, although dissection using scissors is preferred by some due to concern for thermal injury to these delicate structures. Some use a small pledget swab for dissection, but, unless precision and gentleness are used, with any of these methods injury to hepatic arterial branches to the biliary tree could cause bleeding or intimal dissection in the hepatic artery or injury to portal venous tributaries.

Suture material

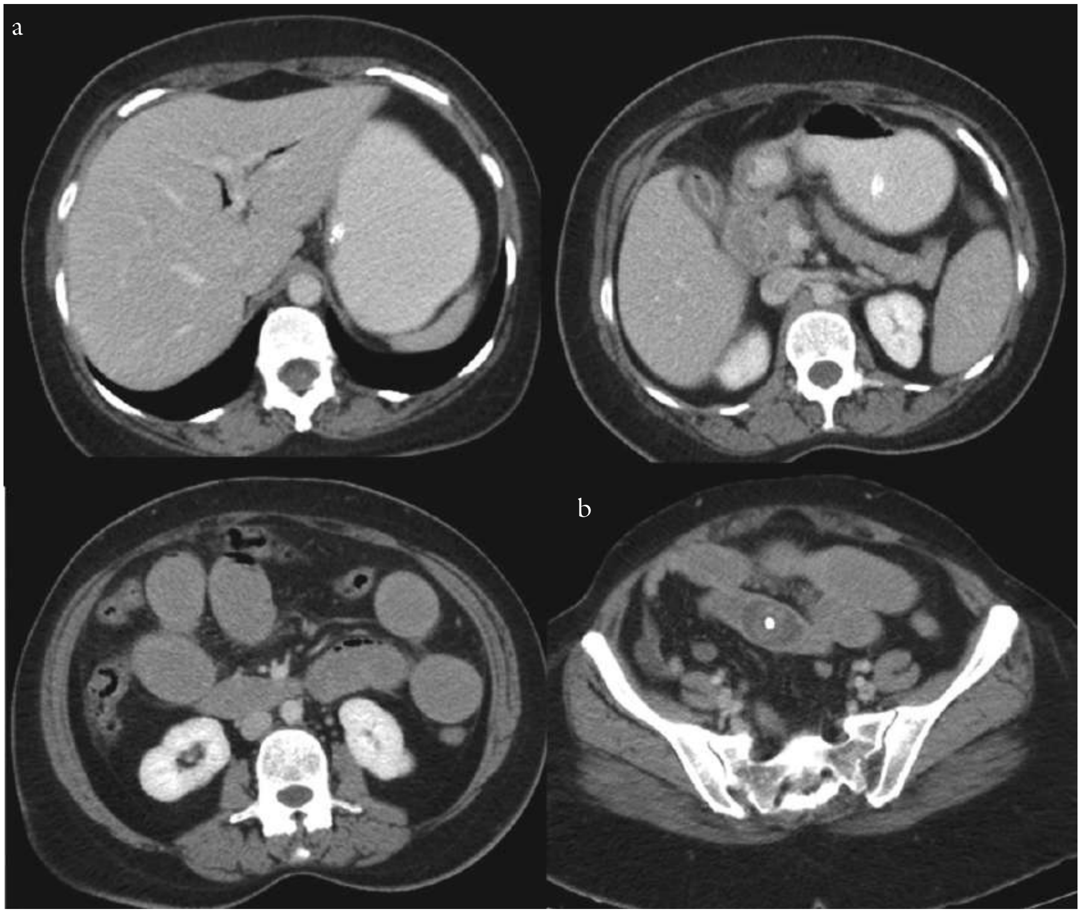
Non-absorbable material should not be used for any biliary anastomosis. Metal clips and non-absorbable sutures can be used to ligate the cystic duct. Polypropylene 5/0 or 6/0 is used for repair of unanticipated bleeding from the hepatic artery or portal vein.

Anastomoses

The principles of biliary anastomoses are similar to those of other gastrointestinal anastomoses, which are discussed in more detail in Chapter 7. Interrupted absorbable sutures are preferred by most surgeons. It is very important to include the mucosa of the bile duct in any anastomosis, as this ensures the lowest anastomotic stricture rate.

OPERATIONS FOR CHOLELITHIASIS

Although gallstones affect about 10% of people in the Western world, more than 80% are asymptomatic. Cholecystectomy is not generally advocated in



10.4 CT scan of gallstone ileus: pneumobilia (a) and stone in ileum (b). ⏎

asymptomatic patients, but exceptions include those with a strong family history of gallbladder cancer, sickle cell disease or hereditary spherocytosis, patients with a porcelain gallbladder (increased risk of malignancy) and those who are on long-term total parenteral nutrition.

The complications of cholelithiasis include biliary colic, cholecystitis, obstructive jaundice, cholangitis, acute pancreatitis, biliary strictures and gallstone ileus (Figure 10.4).

INDICATIONS

Biliary colic

Biliary colic is due to gallbladder distension, and contractions, secondary to a gallstone occluding the cystic duct. The pain ceases when the gallstone drops back into the body of the gallbladder or passes into the CBD. Obstructive jaundice may occur unless the stone passes spontaneously into the duodenum. Following a single episode of biliary colic, the chances of further episodes of biliary pain or complications of gallstones are high (70%), and it is best to consider and recommend elective cholecystectomy.

Acute cholecystitis

The precipitating event for acute cholecystitis is again a stone or sludge impacted in the neck of the gallbladder. If the stone does not become disimpacted (as in biliary colic), the resultant biliary stasis and gallbladder distension trigger the release of prostaglandins, which mediate an acute inflammatory response, often with concomitant bacterial infection. Cholecystectomy is indicated and can be performed safely in most patients if they present within 3–4 days of pain onset. For those presenting later, interval cholecystectomy can be undertaken after an interval of 4–6 weeks, or more, when the acute inflammatory process, which often involves the duodenum and hepatic flexure of colon, has settled.

Acute acalculous cholecystitis

Acute acalculous cholecystitis occurs mainly in patients who are already critically ill. The condition tends to be more rapidly progressive and frequently leads to gangrene of the gallbladder. In these situations, percutaneous, image-guided cholecystostomy under antibiotic cover in the acute phase may be optimal with cholecystectomy later, if needed.

Mirizzi syndrome

Mirizzi syndrome occurs when there is obstructive jaundice secondary to extrinsic compression, or erosion of the CHD, from a large gallstone impacted in the neck of an inflamed gallbladder or cystic duct. Csendes classification is commonly used. Type I occurs due to extrinsic compression of the CHD by a cystic duct calculus, while types II, III and IV describe erosion of the CHD circumference up to one-third, two-thirds and near totally by the gallstone, respectively.

Cholecystostomy: A life-saving non-operative biliary intervention

Cholecystostomy is a radiological salvage procedure in a sick patient with severe acute cholecystitis. Very occasionally, an open cholecystostomy may be required if cholecystectomy is deemed unsafe in a patient undergoing an open operation. The fundus of the gallbladder is opened, the gallstones and biliary sludge are removed and a large Foley, or other self-retaining, catheter is introduced into the gallbladder. A purse-string suture around the opening into the gallbladder secures the catheter, which is then brought out through the abdominal wall.

After an open, or radiological, cholecystostomy, the tube should be left *in situ* for several weeks to allow the development of a track. A tubogram may be useful to check the biliary anatomy and the presence of residual stones. Following removal of the tube, the biliary fistula should close spontaneously within 7–10 days unless there is downstream biliary obstruction. More than 50% of patients treated by cholecystostomy will be asymptomatic during the next 5 years, and not every patient requires a subsequent cholecystectomy.

LAPAROSCOPIC CHOLECYSTECTOMY, ON-TABLE CHOLANGIOGRAPHY AND LAPAROSCOPIC BILE DUCT EXPLORATION

Laparoscopic cholecystectomy is the optimal method for cholecystectomy, where facilities, and skills, are available. Professor Erich Muhe performed the first laparoscopic cholecystectomy at Böblingen, Germany, in 1985 and, since then, the clinical and economic benefits have been proven, with comparable or shorter operating times, shorter hospital stay, more rapid return to full activity and less morbidity and mortality than open cholecystectomy.

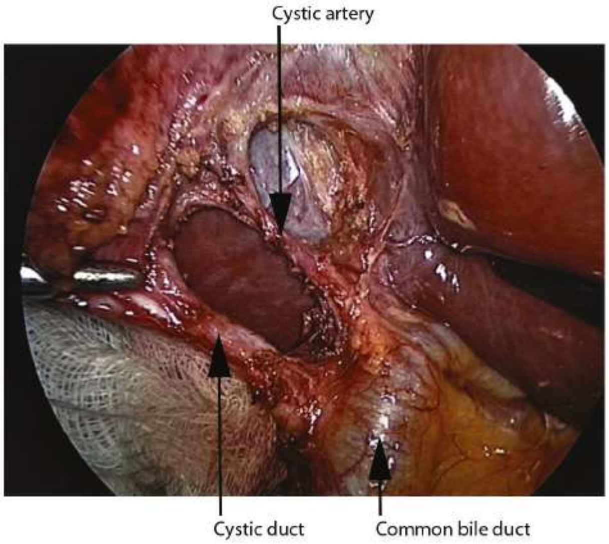
Extensive adhesions and portal hypertension could make laparoscopy difficult. When significant difficulties, or complications, are encountered in a laparoscopic cholecystectomy, or bile duct exploration, conversion to an open procedure (usually needed in 2–5% of cases) should be considered, but this decision will be influenced by the experience of the surgeon. Any of the difficulties encountered at a laparoscopic operation can also occur at open surgery. These difficulties are discussed in the section 'Open cholecystectomy and bile duct exploration' later in this chapter.

Laparoscopic cholecystectomy

Laparoscopic access is established either by an open Hasson technique or Veress needle insufflation. The first port is normally placed an inch cranial to the umbilicus but, if a patient has had multiple previous operations, the peritoneal cavity may be entered in an area not associated with a previous incision. The second 10 mm port is inserted under direct vision, in the midline, in the epigastrium, passing just to the right of the falciform ligament, towards the gallbladder. Two 5 mm ports are introduced, one in the right mid-clavicular and one in the right anterior axillary line, angled towards the gallbladder (see Figure 10.3). The positioning of the patient for optimal visualisation and the preliminary exploration are described above. After dividing adhesions between the gallbladder and omentum or duodenum, the gallbladder fundus is grasped and retracted towards the patient's right shoulder by an assistant. A 5 mm grasper is then placed on Hartmann's pouch and, using the operator's left hand, is retracted to the patient's right, opening up the porta hepatis. The anterior and posterior peritoneum over the neck of the gallbladder is then divided, and Calot's triangle is carefully dissected to isolate the cystic artery and cystic duct: this is a triangle bounded by the inferior surface of the right lobe of the liver, the CHD and the cystic duct and superior border of the gallbladder (Figure 10.5). Care must be taken to stay close to the gallbladder and not dissect close to the junction of the cystic duct and CHD (see Figure 10.7a). Any stones in the cystic duct should be 'milked' towards the gallbladder.

The critical view of safety (CVS) was described by Strasberg in 1995[2] as a tool for safe cholecystectomy and has the following three requirements: (1) all fibrofatty tissue in the hepatocystic triangle should be cleared, (2) two, and only two, structures should be seen entering into the gallbladder and (3) the lower third of the gallbladder should be dissected off the cystic plate with the base of the liver seen clearly in between the two structures. When all three criteria are met, the two tubular structures are securely identified as the cystic duct and cystic artery and can be safely divided.

Routine intraoperative cholangiogram is unnecessary and often hazardous. We recommend its use to guide CBD exploration or when biliary injury is



10.5 An excellent view of Calot's triangle can be obtained at laparoscopic cholecystectomy. (Photograph by kind permission of Tim John, Basingstoke.) ⏎

suspected. A small incision is made in the cystic duct and a cholangiogram catheter, usually an infant feeding tube, is introduced and secured in the cystic duct with a clip. It is important that the cannula is flushed with saline or contrast prior to placement in order to eliminate air bubbles that may masquerade as stones on X-ray. Contrast is then injected while radiologically screening over the right upper quadrant. The points to note on the cholangiograms obtained are (1) biliary tree dilatation, (2) filling defects within the biliary tree, (3) free flow of contrast into the duodenum, (4) tapering of the distal CBD and (5) visualisation of all sectoral tributaries of the hepatic ducts. After satisfactory images have been obtained, the clip is removed and the catheter withdrawn. The cystic duct is then clipped proximally, and distally, to the opening and then divided. Alternatively, in supported laparoscopic and robotic systems, an indocyanine green (ICG) study will depict the biliary anatomy clearly and would help in scenarios where anomalous anatomy or a biliary tract injury is suspected. ICG is not helpful when a bile duct stone needs to be ruled out.

The gallbladder is carefully dissected off the cystic plate. Prior to the final disconnection, and using the gallbladder as a retractor, haemostasis of the gallbladder bed is secured and the positions of the clips placed on the cystic duct and the cystic artery are checked. The dissection is then completed and the gallbladder is retrieved through the epigastric or umbilical 10 mm port, ideally in a retrieval bag. Drainage of the right subhepatic space with a closed-tube drainage system should be considered in selected patients in whom dissection was difficult, making postoperative bleeding or bile leak likely, despite best efforts to identify and solve them during the operation.

Laparoscopic subtotal cholecystectomy

Laparoscopic subtotal cholecystectomy is performed when there is dense fibrosis or inflammation in the hepatic hilum precluding safe dissection of Calot's triangle and demonstration of CVS. There should be no hesitation in proceeding to a laparotomy if continuing laparoscopically seems difficult and/or dangerous. The gallbladder is divided at the level of its neck, where it can be divided safely without injury to the hilar structures. The anterior wall of the gallbladder is opened initially and stones inside the gallbladder should be completely retrieved. Bleeding from the gallbladder wall can be controlled with a bipolar energy source. An attempt should be made to locate the cystic duct orifice from the inside of the gallbladder, and any impacted stones should be cleared. If the cystic duct is patent, golden yellow bile oozes through the cystic duct orifice and is a sign that there are no further stones in the cystic duct. Often, the cystic duct orifice may be obliterated and no bile is anticipated. Any excess cuff of gallbladder is now trimmed. The remaining stump of gallbladder is then closed with an absorbable suture such as polyglactin (Vicryl) or polydioxanone (PDS®). When the posterior wall is densely adherent to the underlying liver parenchyma or in patients with portal hypertension, the posterior wall is left intact, as attempts to remove it may result in excessive bleeding. The mucosa of the posterior wall is ablated using bipolar diathermy. A closed-system drainage tube is usually placed in the subhepatic space and usually removed in 24–48 hours if there is no bile leak.

Laparoscopic bile duct exploration

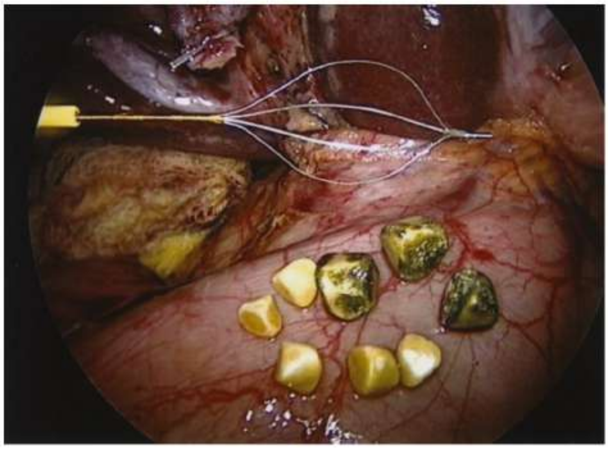
The management of patients with choledocholithiasis is dependent on local resources and expertise. The authors prefer, if feasible, preoperative ERCP and stone extraction, followed by a laparoscopic cholecystectomy. An alternative is to proceed directly to laparoscopic cholecystectomy with intraoperative cholangiography and bile duct exploration if necessary.

If a filling defect is seen within the biliary tree on intraoperative cholangiography, the surgeon may (1) explore the bile duct laparoscopically, (2) convert to an open procedure or (3) perform an ERCP and stone extraction in the early postoperative period. Factors influencing this decision are the skills of the surgeon and the endoscopist, the size of the stone(s), and the diameter of the cystic duct and the CBD.

Approximately 60% of patients may be explored via the transcystic route, with the stones either extracted or pushed into the duodenum using baskets or balloons (Figure 10.6). The cystic duct is then simply secured with clips, or a ligature, at the end of the procedure. When the CBD is dilated, it may be explored laparoscopically via a supraduodenal vertical choledochotomy, taking care not to damage the posterior wall of the CBD. There are several techniques for exploring the biliary tree and the methodology will vary depending on the expertise and equipment available. Options include the use of a biliary Fogarty catheter or a wire retrieval basket, with either fluoroscopic image guidance or direct visualisation using a choledochoscope.

A biliary Fogarty catheter is first passed upwards into the proximal biliary tree and advanced as far as it will go. The balloon is then inflated until slight resistance to downwards traction is felt and the catheter is pulled downwards, maintaining inflation to provide slight resistance. Any calculi appearing at the choledochotomy incision are removed by forceps. The procedure is repeated for both hepatic ducts, in turn, until the surgeon is satisfied that the proximal biliary tree is clear. Exploration of the distal CBD is now undertaken. The Fogarty catheter is passed into the duodenum (judged by the distance it has passed) and the balloon inflated. The catheter is withdrawn until there is resistance, signifying that the balloon is at the sphincter of Oddi. The balloon is partially deflated while maintaining upwards traction until it is felt coming through the sphincter. It is then reinflated to maintain slight resistance to traction and the catheter pulled upwards until calculi, or the balloon, appear at the choledochotomy incision. Calculi are removed and the procedure is repeated until the surgeon is satisfied that no calculi remain. Alternatively, if a filling defect has been identified at intraoperative cholangiography, a wire retrieval basket can be inserted via a choledochotomy and positioned using fluoroscopic control to engage an intraductal calculus, which can then be extracted under fluoroscopic surveillance. This procedure can be repeated for multiple calculi.

If choledochoscopy is available, a similar procedure can be undertaken using a wire retrieval basket but under direct vision rather than under fluoroscopic surveillance. When the surgeon feels that the ducts have been cleared, the CBD and hepatic ducts are irrigated with saline to wash out any calculus debris or blood clots. The surgeon can then inspect the bile ducts under direct vision with a choledochoscope to ensure there are no residual calculi. Alternatively, post-exploratory cholangiogram films are taken. A fine (8 Fr) Foley catheter is inserted into the choledochotomy incision and directed upwards into the proximal biliary tree. The balloon is inflated and a proximal occlusion cholangiogram obtained. The catheter is then introduced into the distal bile duct, reinflated to occlude the duct and a distal cholangiogram performed. Provided that the ampulla is not occluded by a stone, the pressure obtained by using this technique will allow contrast to pass into the duodenum and fully display the lower portion of the bile duct.



10.6 Stones have been extracted from the CBD by laparoscopic transcystic instrumentation with a wire retrieval basket. (Photograph by kind permission of Tim John, Basingstoke.) ⏎

Following demonstration of a satisfactory clearance of the biliary duct system, the bile duct is usually closed primarily. The surgeon may choose to place a plastic endobiliary stent, which can be removed at subsequent endoscopy. Placement of a subhepatic drain is prudent but not essential. When a bile duct has been opened, but cannot be cleared laparoscopically, conversion to an open approach should be considered.

OPEN CHOLECYSTECTOMY AND BILE DUCT EXPLORATION

An open approach to a cholecystectomy is chosen either in resource-poor settings or when laparoscopy is technically difficult due to dense adhesions or inflammation in Calot's triangle.

The first step consists of freeing any inflammatory intraperitoneal adhesions between the gallbladder and adjacent viscera or omentum. Careful packing and retraction can then achieve optimal exposure. A gauze roll, or pack, is placed over the duodenum and this is retracted firmly downwards by the left hand of the assistant or using a self-retaining retractor. A deep retractor is then placed under the right lobe of the liver and this is lifted gently upwards to expose the gallbladder.

There are two principal methods of removing the gallbladder: a retrograde method or a fundus-first method.

Retrograde method

The generally advocated retrograde method involves early dissection and division of the cystic duct, and artery, to expose the CVS, followed by retrograde dissection of the gallbladder off the liver towards the fundus. This early delineation of the key structures reduces the risk of injury to the CBD or right hepatic artery. When distension of the gallbladder prevents easy access to Calot's triangle, the contents should be aspirated and the puncture site closed with a stitch or clamp.

Once CVS is attained, a ligature is then passed loosely around the cystic duct, close to its junction with the CBD. Any stones in the cystic duct should be milked towards the gallbladder and the cystic duct clamped or ligated (Figure 10.7b), close to Hartmann's pouch. The cystic duct is ligated, staying away from the cystic duct–CBD junction. If the cystic duct is particularly wide, it may be advisable to transfix the stump with a 2/0 or 3/0 polyglactin suture.

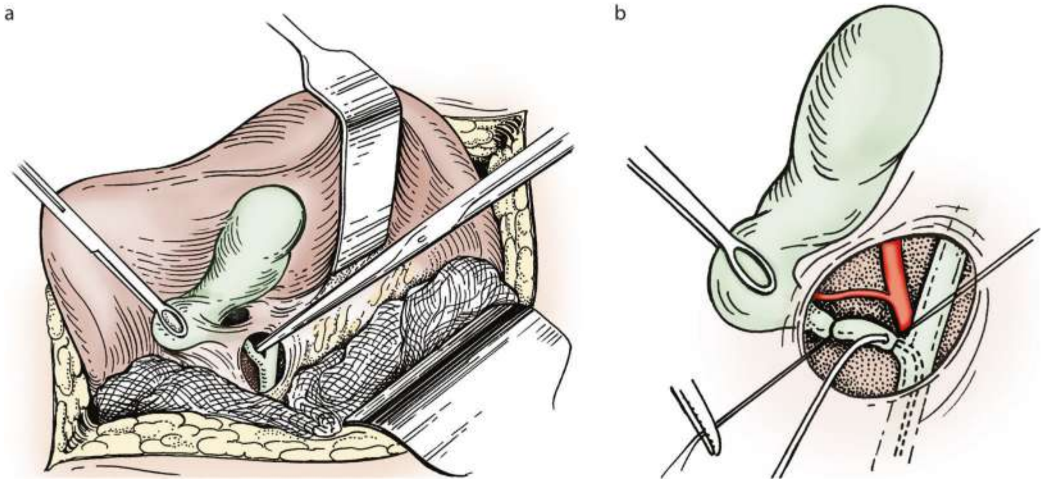
The gallbladder neck is drawn forwards, away from the liver, and the plane between the two is dissected through the cystic plate, a relatively avascular, areolar plane that attaches the gallbladder to the liver. It is very unusual to find any bile leak through the cystic plate. If some bile is encountered, we advise readers to look for sectoral duct injury, rather than presuming this to be an accessory bile duct (of Luschka).

Open transcystic bile duct exploration is very similar, as described earlier in the laparoscopy section.

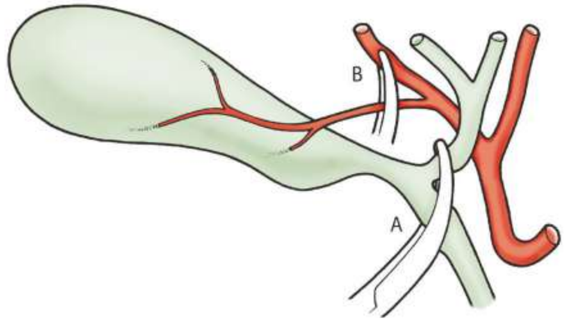
'Fundus-first' method

This method is advised only when severe inflammatory changes in the hepatic hilum prevent safe initial dissection of Calot's triangle. Paradoxically, the fundus-first method also carries risks of injury, particularly to the CBD and right hepatic artery. Excessive traction on the mobilised gallbladder may pull these structures out of their normal alignment, rendering them liable to be clamped or included in a ligature (Figure 10.8).

Separation of the gallbladder from the liver bed is commenced at the fundus, the peritoneal sheath being divided (with scissors or diathermy) on both sides where it is reflected onto the liver. It is important not to breach the cystic plate or, if the cystic plate is obliterated by inflammation, not to dissect deeply into liver parenchyma, deep to the cystic plate. If great care is not taken, as dissection proceeds to reach the hilum, instead of reaching the cystic duct, the CHD is encountered and potentially injured. As the dissection proceeds, the gallbladder is finally attached only by the cystic artery and cystic duct. Any bleeding should be controlled and stopped before proceeding with further dissection to maintain clear vision. If, due to marked inflammation, isolation of the cystic duct and artery is thought to endanger the right hepatic artery or the CBD, it is better to leave part of the neck of the gallbladder *in situ* (a subtotal cholecystectomy) than to persevere with a hazardous dissection.



10.7 Open cholecystectomy by the retrograde method. A longer incision in the peritoneum than illustrated here will allow better exposure of the anatomy. (a) Exposure of the cystic duct at its junction with the CHD, in the right free border of the lesser omentum. (b) The cystic duct has been ligated and a cannula inserted into the CBD for cholangiography. The cystic artery has been identified. ⏎



10.8 The potential for injury to the CBD and right hepatic artery may be increased in the 'fundus-first' dissection, as traction on a fully mobilised gallbladder can distort the anatomy both at the termination of the cystic duct (**A**) and at the origin of the cystic artery (**B**). ⏎

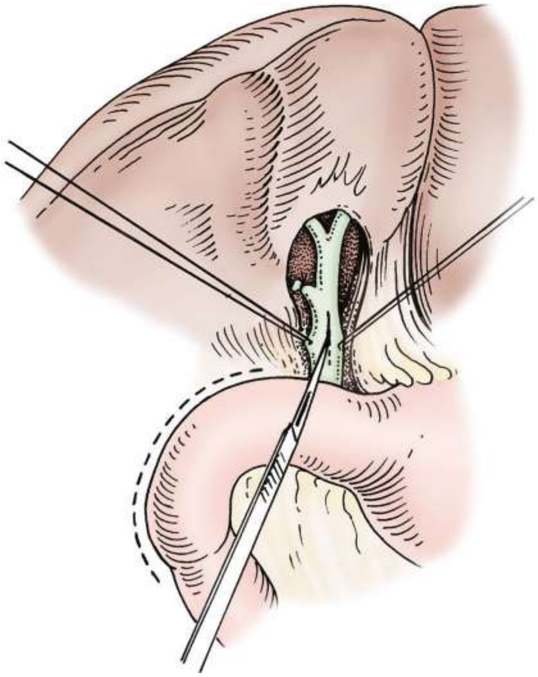
Drainage of the subhepatic space is unnecessary unless there are specific concerns, as discussed in the laparoscopic section earlier.

Supraduodenal choledochotomy

When bile duct exploration cannot be undertaken via the cystic duct, the supraduodenal portion of the CBD, lying in the free border of the lesser omentum, is relatively accessible. In the majority of cases, exploration of the duct is for suspected calculi, and the gallbladder will have been removed earlier in the operation. Kocherisation of the duodenum is no longer recommended as the initial step, as it is usually unnecessary. Kocherisation is the mobilisation of the duodenum by a lateral peritoneal incision, which opens the plane behind the duodenum and head of the pancreas so that both can be rotated anteriorly.

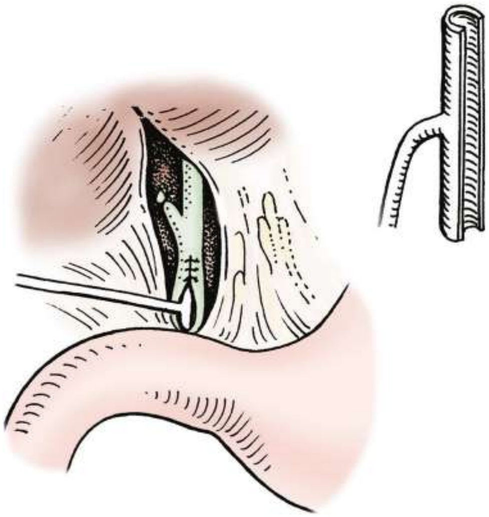
Operative procedure The peritoneum over the supraduodenal portion of the CBD is incised and the anterior surface cleared of peritoneum, and fatty tissue, over a distance of 1.5 cm. One or two small vessels in the immediate supraduodenal region may need to be controlled by fine sutures. Aspiration of the CBD using a fine needle helps guide the location of the CBD if dense inflammation, or fibrosis, is present. Stay sutures of 4/0 PDS/polyglactin are inserted near the lateral borders of the duct, and a 1.5–2.0 cm longitudinal incision is made between them (Figure 10.9). About 10 mL of bile should be sent for culture. Some floating stones may emerge with the first rush of bile, and these should be retrieved. A gentle attempt should now be made to milk any palpable stones towards the choledochotomy incision, where they may be removed using gallstone forceps.

The duct is now formally explored for residual stones, some of which may be palpable. A wide variety of instruments are available for this purpose. Rigid bougies or forceps (e.g. Desjardin or Maingot forceps) were traditionally used but, unless great care is exercised, damage to the duct, particularly at its lower end, may result, with subsequent stricture formation. It is therefore recommended that the initial exploration is made with a Fogarty balloon catheter as described earlier in the laparoscopic section. At an open exploration, confirmation that the catheter has passed into the duodenum is made by palpation of the inflated balloon. Should the Fogarty catheter fail to enter the duodenum (usually due to an impacted and palpable stone), Kocherisation of the duodenum may be helpful. Further gentle exploration with biliary forceps, using the left hand behind the pancreatic head to guide the instrument into position, will usually result in successful stone extraction. Management of impacted, and apparently unmovable, stones will be considered later. Confirmatory post-exploration cholangiography or choledochoscopy is then undertaken, as in a laparoscopic operation, and finally the duct is closed with, or without, an endobiliary stent or, occasionally, over a T-tube. Most hepatobiliary surgeons no longer recommend the routine use of a T-tube if the duct has been seen to be clear of stones on choledochoscopy or post-exploration cholangiogram.



10.9 Choledochotomy. The supraduodenal CBD is exposed and opened longitudinally between stay sutures. The dotted line shows the peritoneal incision for Kocherisation should this prove necessary. ⏎

When a T-tube is used, a relatively fine 10- or 12-Fr gauge is satisfactory. The short limbs are inserted into the CBD via the choledochotomy incision (Figure 10.10), which is closed using interrupted



10.10 T-tube drainage of the CBD. The final suture in the duct, below the T-tube, still has to be inserted. ⏎

4/0 polyglactin/PDS sutures. The long limb of the T-tube is brought out to the surface through a stab incision, taking the most direct route. A small-calibre tube drain can also be placed in the subhepatic space.

A T-tube cholangiogram is then performed 3–4 weeks later to ensure there are no retained stones. If the cholangiogram is normal, the T-tube is clamped and then removed. Following removal of the T-tube, there may be a small cutaneous bile leak that persists for 1–2 days.

DIFFICULTIES AND COMPLICATIONS DURING CHOLECYSTECTOMY AND EXPLORATION OF THE CBD

Cystic duct

There is sometimes difficulty in isolating the cystic duct due to dense inflammation in Calot's triangle making the anatomy impossible to elucidate. This problem is often encountered when complications of cholecystitis mandate an untimely operation in a patient whose symptoms lasted a week or more preoperatively. Percutaneous or surgical cholecystostomy should be considered as a safer alternative. Difficulty can also arise when the terminal portion of the cystic duct runs parallel to the CHD before entering it or when the cystic duct winds around the CHD (see element C in Figure 10.2). We recommend leaving a portion of cystic duct *in situ* or even performing a subtotal cholecystectomy rather than persevering with a high risk of bile duct injury. Difficulty can also be due to a stone lodged in the neck of the gallbladder with intense inflammation around it. Combined pressure from the stone and the inflammation may obstruct the CHD and cause jaundice (Mirizzi type I). The stone must be released by a lateral incision to minimise any risk to the CHD, but removal of the gallbladder neck will probably be unwise. A temporary bile leak should be anticipated and a drain placed to the area. Mirizzi syndrome types II–IV situations will require repair of the CBD using cholecysto-choledochorraphy or, preferably, hepaticojejunostomy reconstruction.

Simple ligation of a short wide cystic duct (see element A in Figure 10.2) may be insecure and it also has the potential to distort and narrow the CBD. A sutured closure with an absorbable suture may be a better alternative.

Haemorrhage

Haemorrhage from a torn cystic artery or a slipped ligature is likely to be profuse. Local pressure with a gauze held on the bleeding point, maintained for several minutes, will usually reduce bleeding sufficiently to allow the bleeding vessel to be identified and secured when the pressure is released. Conversion to an open operation may be prudent if profuse bleeding continues. If necessary, the hepatic artery may be temporarily occluded by a soft bowel clamp or a vascular bulldog clamp placed on the free border of the lesser omentum (the Pringle manoeuvre). Significant haemorrhage should raise suspicion that there may be a right hepatic artery injury, which, if identified, should be carefully repaired by an expert. Ligating an injured right hepatic artery is better than a poorly performed repair as life-threatening arterial pseudoaneurysm could result in the latter situation. As an intact left hepatic artery and hilar plate maintain hepatic and biliary arterial supply, isolated right hepatic artery ligation is well tolerated in many patients.

IATROGENIC BILE DUCT INJURIES

Most injuries to the biliary tree are iatrogenic. They are usually due to inadequate demonstration of the anatomy of Calot's triangle at cholecystectomy, and they are the most feared complication of cholecystectomy. A segment of the CBD may be inadvertently damaged, clipped or included in a ligature (see Figure 10.8), resulting in a major bile leak or biliary obstruction. A partial circumference injury may heal but cause a significant stricture of the duct. CBD injuries can also occur during mobilisation of the duodenum in a gastrectomy. When a surgeon suspects that a bile duct injury has occurred, it is very important not to compound the damage by making a hurried decision or an inappropriate attempt at repair. If at all possible, the help and support of a colleague who was not involved in the initial injury should be sought. Such injuries are potentially serious and should be managed by a hepatobiliary surgeon, if available, as there is good evidence that long-term results are significantly better if the initial repair or reconstruction is undertaken by a specialist. Simple drainage of the site of the injury, and of the subhepatic space, followed by referral to a specialist unit is often the best approach.

Immediate primary repair (duct–duct)

Primary repair of an injured CBD or CHD is very rarely the right choice of repair. However, if certain conditions are met, it could be considered:

- The injury is identified during the operation.
- The injury is confined to a small length of just the lateral wall of the CBD/CHD (less than 2 cm).
- There is no thermal injury to the CBD.
- A good-quality operative cholangiogram proves the limited extent of the injury.
- There is no loss of segmental blood supply.
- The help of an expert hepatobiliary surgeon is available.
- Fine absorbable sutures (5/0 or 6/0) are available.

Such limited injury to a CBD or CHD is uncommon and the best solution for an injured CBD or CHD is biliary-enteric reconstruction.

Immediate or early biliary-enteric reconstruction

Immediate performance of biliary-enteric reconstruction to repair an injured CHD or CBD is an excellent choice of operation, as it prevents morbidity of external biliary fistula and, sometimes, potential mortality from biliary sepsis. However, it must be done only when certain very specific conditions are met:

- Either a cut injury is identified during the operation or the injury resulted in ligation of the CBD or the CHD that does not cause local or generalised biliary peritonitis.
- An expert hepatobiliary surgeon is available to perform the repair.
- Adequate lighting is available in the operating room.
- Good costal margin retractors are available to provide steady exposure.
- Fine sutures (5/0 or 6/0) are available.

The injured ends of the CHD, or lobar hepatic ducts, are freshened using sharp scissors to remove any diathermy-injured tissue, until healthy tissues are visualised and to a level where fresh arterial bleed oozes out from the cut end of the duct(s). At this point, a Roux loop of jejunum is used to perform a tension-free, mucosa-to-mucosa hepaticojejunostomy. Principles that guide performance of a hepaticojejunostomy are described later.

IMPACTED STONE AT OPEN BILE DUCT EXPLORATION

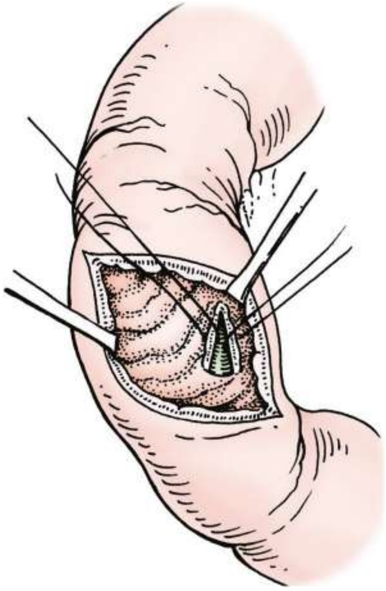
If a stone remains impacted at the lower end of the CBD, despite routine measures to remove it, the surgeon has the choice of a number of approaches, depending on the fitness of the patient and the availability of endoscopic skills:

- Leave the stone *in situ*, drain the CBD by T-tube for 2–3 weeks to allow inflammation to settle, and then perform an ERCP, sphincterotomy and endoscopic stone removal. For the very sick patient, this may be appropriate, but truly impacted stones can be very difficult to remove at ERCP and certainly stones over 15 mm are not suitable for this technique.
- Leave the stone *in situ* and perform a side-to-side Roux-en-Y hepaticojejunostomy, as described later.
- Remove the stone via a transduodenal sphincteroplasty. After duodenal Kocherisation, an oblique anterolateral incision is made in the second part of the duodenum. Stay sutures are then inserted in the medial wall of the duodenum on either side of the ampulla (Figure 10.11). An incision is made directly over the stone, which is then extracted. The incision in the wall of the duodenum and lower end of the bile duct is then enlarged using Potts scissors, to a minimum length of 15 mm, and converted to a formal sphincteroplasty by approximating duodenal and bile duct mucosa using interrupted 4/0 PDS sutures. Care must be taken to ensure apposition of mucosa at the apex of the incision. The duodenotomy incision is then closed in a single layer. Supraduodenal T-tube drainage is not normally necessary following this procedure.

POSTOPERATIVE COMPLICATIONS OF BILIARY SURGERY

RETAINED STONES

Management of retained CBD stones is usually by ERCP in the postoperative period, although some small stones may pass spontaneously. ERCP may not be suitable for stones retained high in the biliary tree, and may be unsuccessful if the stone is firmly impacted at the lower end.



10.11 Transduodenal sphincteroplasty. ⏎

Re-operation will be required in the event of failure, or non-availability, of ERCP. Transduodenal sphincteroplasty, as described above, is one option for retained stones in the distal CBD (see Figure 10.11). Alternatively, side-to-side hepaticojejunostomy provides excellent biliary diversion in this setting.

POSTOPERATIVE BILE LEAKS AND BILIARY FISTULAE

A bile leak may present through a subhepatic drain placed at operation or the bile may collect intra-abdominally and present as generalised biliary peritonitis, a localised collection or a discharge of bile from the wound. The surgeon must have a high index of suspicion in any patient who is not well after cholecystectomy.

Fever, upper abdominal or chest pain, tachypnoea, tachycardia and hypotension are classical signs. An abdominal ultrasound or CT scan should be performed and any free fluid or collection aspirated to determine if it is bile stained. If bile leak is confirmed, the initial management is to start broad-spectrum antibiotics and intravenous fluids and perform percutaneous/operative drainage of a biloma in anticipation of a controlled biliary fistula.

A biliary fistula following cholecystectomy is likely to be due to a bile duct injury. Management will depend on the type of injury, the nature and location of which must be defined with MRCP, when sepsis has been controlled. ERCP could be done in highly selected patients in whom MRCP demonstrates that continuity of the CBD or CHD is maintained, thereby suggesting that the bile leak is from either the cystic duct stump or lateral injury to the CBD or CHD. In both of these situations, ERCP solves the problem in the majority.

If ductal injury is major, and the conditions for immediate or early repair of major bile duct injury as described above are not met, delayed repair should be performed after the external biliary fistula heals completely, either by complete fibrosis of the injured stump and development of obstructive jaundice or by the injured end of the biliary tree forming a spontaneous internal fistula, usually to the duodenum. Generally, delayed repairs are performed between 6 and 12 weeks from the time of injury.

Occasionally, external biliary fistula does not heal, even at 12 weeks. In this situation, performance of percutaneous transhepatic biliary drainage (PTBD) by a highly experienced interventional radiologist, who is capable of performing this procedure in this setting of an undilated biliary tree, is very helpful and changes the situation to a controlled biliary fistula. Hepaticojejunostomy could then be performed 7–10 days later when the inflammation subsides.

LATE REPAIR OR RECONSTRUCTION OF THE BILE DUCTS AFTER BILIARY INJURY

Late repair of a severed or stenosed duct is a difficult operation and should be performed only by an experienced hepatobiliary surgeon. The duct is likely to be buried in dense scar tissue and the ends may be widely retracted. The reconstruction performed depends on the level of injury, as classified by Bismuth and Majno[3] or by an even more elaborate classification proposed by Strasberg.[2] The most successful method of reconstruction is to perform a hepaticojejunostomy, anastomosing the proximal hepatic or biliary duct(s) to a Roux loop of jejunum.

Hepaticojejunostomy with a Roux loop

This procedure is described here for the reconstruction of severed or stenosed ducts following iatrogenic injury, but the same technique is used for biliary reconstruction in a variety of other pathologies. It is the preferred method of surgical biliary drainage in most instances, and is the standard method of biliary reconstruction following bile duct resection for conditions such as a choledochal cyst.

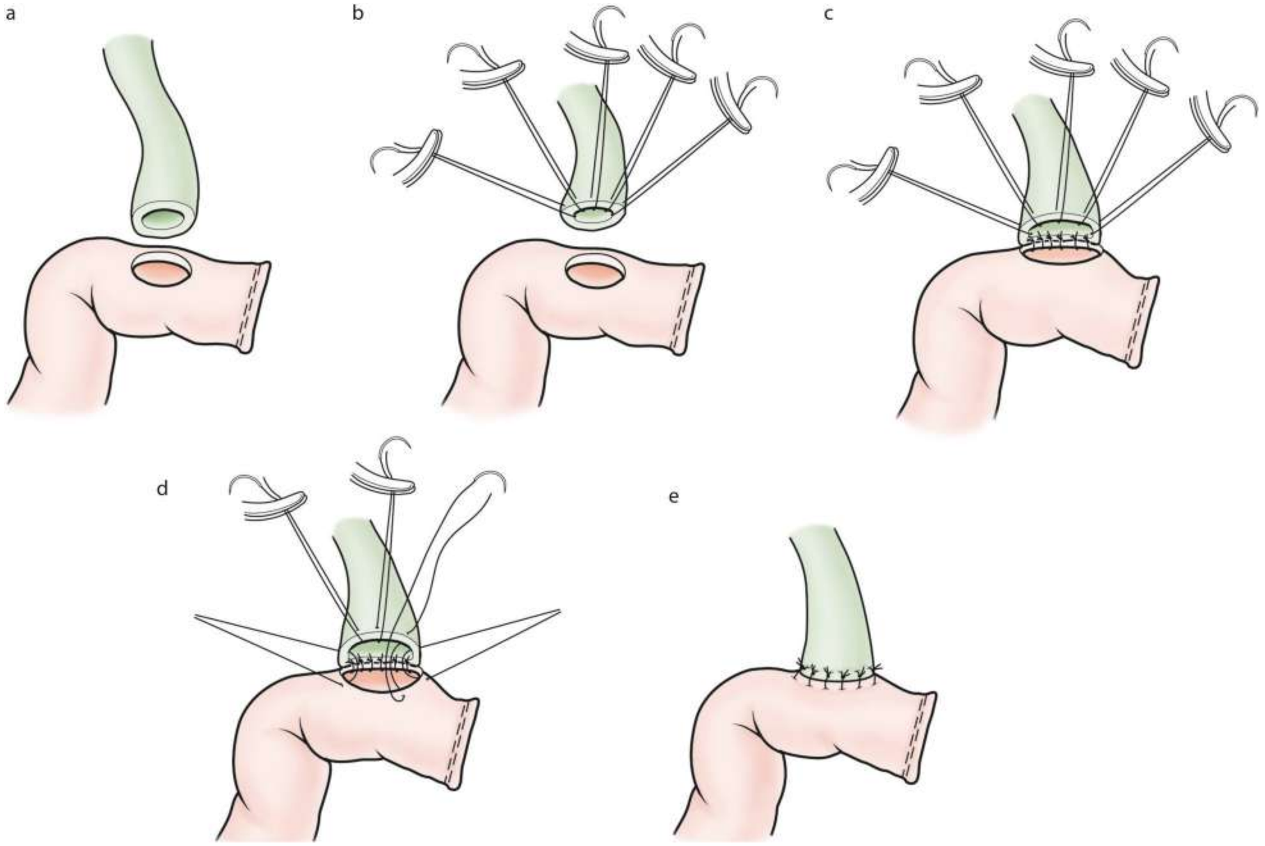
The principles of hepaticojejunostomy are the same as those of any other anastomosis. The principles are:

- Anastomose tissues with good vascularity: trim all scar tissue from the hepatic ducts.
- Look for, and anastomose, all anomalous ducts shown in MRCP.
- There should be no circumferential dissection of biliary or hepatic ducts, and the posterior hilar plate vascularity should be preserved.
- There should be an adequate sized lumen and, in this context, the opening in the hepatic or biliary duct should be 2.5–3 cm in size.
- It should be tension free: there should not be any traction on the anastomosis by the Roux loop of jejunum.

The hilar plate, a continuation of the loose areolar cystic plate that binds the gallbladder to the liver, is a loose areolar plane that connects the hepatic ducts to the posteroinferior surface of the liver at the hepatic hilum. It is lowered by sharp dissection using short currents of monopolar pencil diathermy or scissors. The easiest place for the dissection is close to the umbilical fissure, where scarring is minimal. This exposes the anterior wall of the left hepatic duct, which is then opened widely. The right hepatic duct can then be traced from here and also widely opened.

The jejunum is transected 25–30 cm distal to the duodenojejunal flexure and its closed distal end is brought up to the subhepatic space in a retrocolic position to the right of the middle colic vessels. Voyles and Blumgart described the most popular technique for hepaticojejunostomy in 1982.[4] The biliary anastomosis is performed using a single layer of interrupted absorbable sutures, preferably PDS 4/0, 5/0 or 6/0 based on the thickness of the duct. We preferably perform side-to-side anastomosis of the sectoral hepatic ducts or CHD onto the jejunum, as this preserves posterior hilar plate vascularity.

An incision into the side of the jejunum must be made of a size appropriate for the diameter of the opened hepatic duct (Figure 10.12a). Preplaced sutures are positioned on the anterior wall of the bile duct and held, if the hepatic ducts are deep and difficult to access. The sutures are passed from outside to inside through the duct. The needles are retained and are held for completion of these anterior sutures after the back of the anastomosis has been finished



10.12 Hepaticojejunostomy. (a) An incision is made in the Roux loop of jejunum. (b) The anterior sutures are only in the bile duct and are used to display the posterior wall of the duct while the posterior sutures are inserted. (c) The posterior sutures are tied. (d) The anterior sutures are completed. (e) The anastomosis is completed as the anterior sutures are tied. ⏎

(Figure 10.12b). The anterior sutures are then elevated as retraction to expose the back wall of the duct, and the posterior sutures are all inserted, but not tied. These sutures are inserted from inside to outside on the jejunum and from outside to inside on the duct. After all sutures are in place, they are held taut and the jejunum is 'railroaded'/'parachuted' down into place and the sutures are tied (Figure 10.12c). The knots of the posterior layer are thus on the inside. The first and last sutures of the back row are held to steady the anastomosis, and all the other sutures are cut short. The front of the anastomosis is then completed using the sutures that were placed in the front of the bile duct at the beginning of the procedure. The needles are passed from inside to outside through the jejunum (Figure 10.12d). When all sutures are completed, the knots are tied (Figure 10.12e). The enteroenterostomy is then fashioned approximately 60 cm distal to this anastomosis.

Difficult situations in hepaticojejunostomy

- If the hepatic duct injury, or other pathology, destroys the whole of the CHD, adequate biliary drainage can be obtained only by a biliary-enteric anastomosis to the left and right hepatic duct or to their intrahepatic branches.
- If a right hepatic duct injury is too high, and the duct is completely separate from the left hepatic duct, preoperative placement of PTBD could help in localisation of the duct.
- In a very high right hepatic duct injury, where it is impossible to obtain any stump of right hepatic duct to perform biliary-enteric anastomosis, we have, on occasions, performed a right hepatectomy and a wide biliary-enteric anastomosis to the left hepatic duct. This decision prevents recurrent cholangitis affecting the right lobe of the liver, which will be an invariable sequel of a technically poor right hepatic duct-enteric anastomosis. Such instances are very rare and a decision to proceed must be made as a final resort only by a highly experienced surgeon.

OBSTRUCTIVE JAUNDICE

Numerous benign and malignant pathologies could cause biliary obstruction. Treatment depends on aetiology and the level and extent of biliary stricture (Table 10.1). Treatment options involve either resection of the affected area and reconstruction in some patients or bypass of the obstructed biliary tree by hepaticojejunostomy in others.

Most benign pathologies that cause obstructive jaundice cause incomplete obstruction and are characterised by severe abdominal pain and cholangitis. Most patients with malignant obstructive jaundice have complete biliary obstruction (with the notable exception of periampullary cancer that often necroses resulting in intermittent jaundice). Unless malignancy is advanced, these patients do not have pain, are deeply jaundiced, have intense pruritus and rarely have cholangitis at presentation.

SPECIAL CONSIDERATION IN SOME BILIARY STRICTURES

Ascaris infestation

Ascaris worms can enter the biliary tract through the duodenal ampulla, where they cause intermittent partial obstruction, irritation and infection. MRCP imaging is diagnostic in most patients. Antihelminthic therapy with albendazole, followed by ERCP to extract worms, can eliminate the disease in most patients. However, in rare instances, where parasitic load is high or a large number of

Table 10.1 Aetiology of biliary strictures at different levels ⏎

Level of biliary obstruction	Benign	Malignant
Proximal	• Iatrogenic biliary injury: surgical • Recurrent pyogenic cholangitis	• Gallbladder carcinoma • Hilar cholangiocarcinoma • Intrahepatic cholangiocarcinoma near hilum • Hepatocellular carcinoma near hilum
Distal	• Choledocholithiasis • Chronic pancreatitis • Lymphadenopathy: tuberculosis • Periampullary diverticulum: Lemmel syndrome • Iatrogenic injury: endoscopic	• Pancreatic head cancer • Ampullary carcinoma • Distal cholangiocarcinoma • Duodenal carcinoma • Metastatic lymphadenopathy
Any level of biliary tree	• Primary sclerosing cholangitis • Parasites: *Ascaris*, echinococcal cysts	• Metastatic lymphadenopathy

dead worms occupy the bile duct, laparoscopic or open bile duct exploration may be required to clear the biliary tree. Intraoperative cholangiogram or choledochoscopy could guide the clearance of parasites. Hepaticojejunostomy may be required in the rare scenario where a biliary stricture has formed due to an inflammatory reaction.

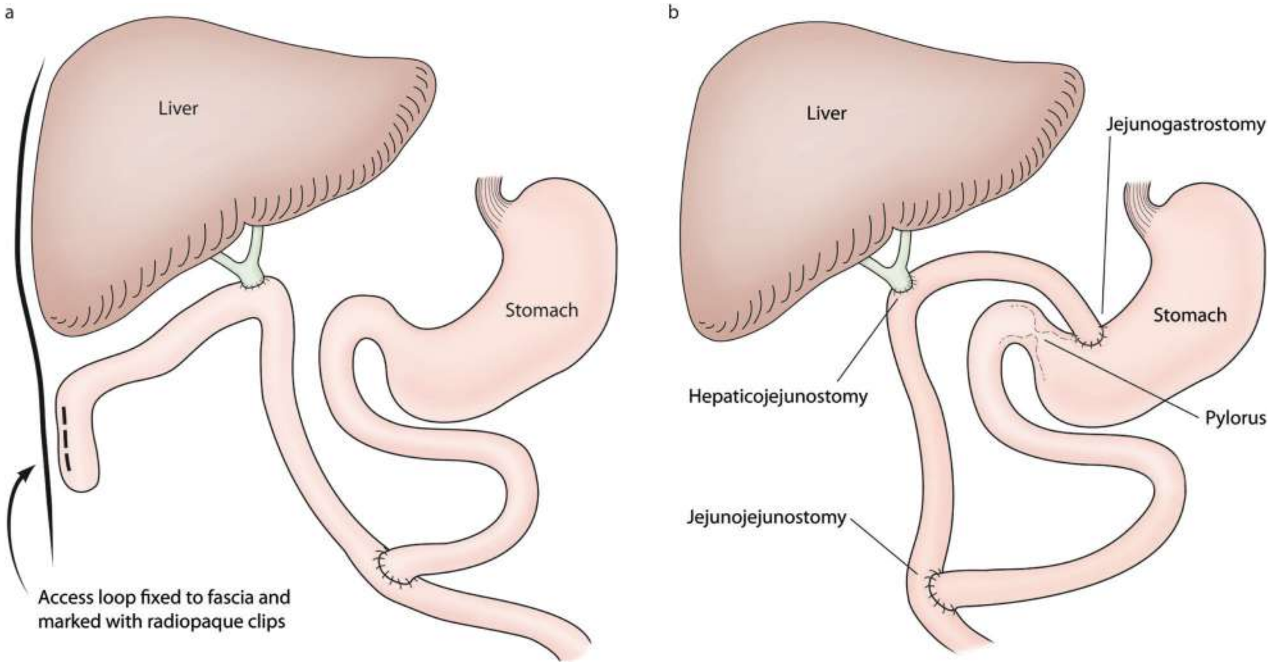
Recurrent pyogenic cholangitis: Gastric and radiological access loops

Clonorchis sinensus (oriental liver fluke), *Opisthorchis viverrine* (South-Asian liver fluke) and *Opisthorchis felineus* (cat liver fluke) are parasitic infections in which humans are the definitive host in which the adult worm lives. The infestation is acquired by eating poorly cooked, infected flesh of freshwater fish from which the encysted metacercariae are released into the duodenum. These then penetrate through the ampulla of Vater and reach the biliary tree of humans, where the adult stage develops and lives for 25–30 years. The acute phase of infection presents with fever, dyspepsia and abdominal pain 2–4 weeks after ingestion and is diagnosed by finding ova in the stools at stool microscopy. Praziquantel and albendazole are the first- and second-line treatments, respectively, recommended by the Centers for Disease Control and Prevention (CDC).

The chronic phase of infection is due to an inflammatory reaction mounted by the body against the parasites. Cholecystitis, choledocholithiasis, pancreatitis, intrahepatic biliary strictures and biliary tract calculi, with consequent liver abscesses, occur a few years later. In the long term, persistent inflammation may lead to cholangiocarcinoma.

Surgical treatment is required for the cholangitis due to intrahepatic biliary strictures and calculi due to recurrent pyogenic cholangitis where resection of the affected portion of liver is required if the disease predominantly affects one side of the liver. For biliary strictures, hepaticojejunostomy is required after clearance of intrahepatic calculi by choledochoscopy. Strictures often persist and, hence, calculi recur. In this situation, the performance of gastric or radiological access loops may help in performing endoscopic or radiological intervention for recurrent calculi or stricture.[5,6]

In a radiological access loop, a metal marker is placed in the jejunal Roux loop's surface, which could be punctured percutaneously, after identification at CT scanning, and subsequently intervention for a biliary stricture or calculi is performed by instrumentation through this loop (Figure 10.13a). In a gastric access loop, the end of a Roux loop used for hepaticojejunostomy is anastomosed to the stomach from which endoscopic access to the proximal biliary tree becomes possible (Figure 10.13b). The choice of radiological or gastric access loop is guided by the expertise available for radiological or endoscopic intervention in each centre.



10.13 Hepatic access loops. (a) A subparietal access loop, which is easily entered radiologically. (b) A gastric access loop, which can be entered at endoscopy. ⏎

Choledochoduodenostomy

In older patients with a healthy duodenum and distal bile duct obstruction due to large calculi, choledochoduodenostomy provides reliable biliary drainage and prevents recurrent biliary obstruction. This procedure is simpler and easier to perform than hepaticojejunostomy in resource-poor settings.

Primary sclerosing cholangitis

Primary sclerosing cholangitis (PSC) is a progressive, chronic cholestatic syndrome characterised by diffuse fibrosing inflammation of the intra- and extrahepatic bile ducts. It is an autoimmune disease and is associated with ulcerative colitis in about 70% of cases. PSC leads to biliary cirrhosis, portal hypertension, cholangiocarcinoma and liver failure. No effective medical treatment is available. While a dominant extrahepatic biliary stricture may be treated by endoscopic stenting, or hepaticojejunostomy, liver transplantation is curative.

PALLIATIVE RELIEF OF BILIARY OBSTRUCTION

Definitive treatment of biliary obstruction to the distal biliary tree, caused by periampullary and pancreatic head cancer, is by Whipple's pancreaticoduodenectomy and is described in Chapter 11. A Whipple's resection should be performed only if no metastatic disease is detected. In the presence of metastatic disease, palliation of the intense pruritus caused by obstructive jaundice is best provided by endoscopic placement of self-expanding biliary stents (SEMSs), aided, or replaced, by percutaneous transhepatic SEMS placement in those with poor endoscopic access.

In rare instances in which the diagnosis of metastatic disease is not made by a preoperative contrast-enhanced CT (CECT) scan of the abdomen and pelvis and is only made at operation, construction of a hepaticojejunostomy by the technique described above may provide durable palliation.

We do not recommend the performance of cholecystojejunostomy, as biliary drainage by this method is unreliable.

TUMOURS OF THE BILE DUCTS

BENIGN TUMOURS OF THE BILIARY TREE

Benign tumours of the bile ducts are very uncommon and include epithelial (adenoma and cystadenoma) and non-epithelial (neurofibroma, lymphangioma and haemangioma) lesions. Management of the lesions in the supraduodenal, extrahepatic biliary tree is by cholecystectomy and excision of the affected segment of biliary tree and hepaticojejunostomy to relieve the biliary obstruction. Non-obstructive benign lesions in the retroduodenal and intrapancreatic biliary tree can be followed up without operation if the diagnosis cannot be proven by endoscopic ultrasound-guided biopsy.

MALIGNANT TUMOURS OF THE BILIARY TREE

Cholangiocarcinoma

The incidence and recognition of cholangiocarcinoma are increasing. Cholangiocarcinoma is associated with conditions causing chronic inflammation, such as PSC, parasitic infections (*Clonorchis sinensis*) and Caroli's disease, or with exposure to carcinogens such as aflatoxin or vinyl chloride. Cholangiocarcinomas are often associated with a dense desmoplastic reaction in the surrounding biliary epithelium and tumours exhibit submucosal spread or perineural invasion. Their extent is thus difficult to assess macroscopically.

Cholangiocarcinomas are classified based on where the epicentre of the lesion is:

- *Intrahepatic cholangiocarcinoma*: epicentre in liver parenchyma
- *Hilar cholangiocarcinoma*: epicentre at the confluence of hepatic ducts
- *Distal cholangiocarcinoma*: epicentre usually in the intrapancreatic part of the CBD

Intrahepatic cholangiocarcinoma is managed by liver resection if adequate liver remnant can be left after resection in patients without metastatic disease. Distal cholangiocarcinoma is managed by Whipple's pancreaticoduodenectomy if there is no metastatic disease.

Hilar cholangiocarcinoma

Patients with cholangiocarcinoma usually present after the sixth decade of life with progressive jaundice, intense pruritus, pale stools and weight loss. A combination of MRCP imaging (a biliary map) and triple-phase CECT of the abdomen and pelvis (a vascular map) are optimal imaging in the diagnosis and assessment of the extent of disease.

MRCP shows an abrupt cut-off of the confluence of the hepatic ducts and the variable extent of the lesion into the right, left or bilateral intrahepatic biliary tree. MRCP provides a near-perfect roadmap of both the obstructed and the unobstructed parts of the intra- and extrahepatic biliary tree and is far superior to invasive techniques such as percutaneous transhepatic cholangiogram or ERCP for assessing the extent of disease. Triple-phase CECT of the abdomen and pelvis provides the following information:

- The presence of metastatic lesions in the liver, periportal/para-aortic lymph nodes, omentum or peritoneal cavity.
- The precise anatomy and course of the hepatic artery and its branches, which is variable. The right hepatic artery usually courses posterior to the confluence of the hepatic ducts (where the epicentre of the lesion is) and is often involved. When a CT scan reveals a replaced right hepatic artery, originating from the superior mesenteric artery and coursing posterolateral to the portal vein, the artery is less commonly involved.
- The involvement of the portal vein and its branches.

Preoperative tissue diagnosis is not mandatory, as radiological findings are classical, but tissue diagnosis is recommended in patients with atypical radiological findings and in patients with borderline fitness for a major operation. Tissue may be obtained from ERCP and biliary brushings, endoscopic ultrasound-guided biopsy or spyglass cholangioscopy. Spyglass cholangioscopy offers the advantage of direct visualisation and biopsy.

Operable hilar tumours require excision of the confluence of the right and left hepatic ducts combined with a hemihepatectomy and caudate lobectomy (see Chapter 12).

Patients with inoperable disease usually die from progressive biliary obstruction with cholangitis, rather than from metastatic disease. Hence, effective palliation is placement of a combination of biliary SEMSs, plastic stents and external biliary drainage to relieve obstructing lesions by percutaneous transhepatic, ERCP-guided or rendezvous methods. Drainage palliates pruritus, which is the major symptom that affects quality of life.

CARCINOMA OF THE GALLBLADDER

Although gallbladder cancer is rare, it is the most common form of biliary tract malignancy. Carcinoma is found in 1–2% of cholecystectomy specimens and is most common in older women. Risk factors for malignancy include:

- Gallbladder polyps greater than 1 cm in diameter
- Porcelain gallbladder (due to intramural calcification)
- Anomalous pancreaticobiliary duct junction
- Patients in the Gangetic belt of North and East India and Andean areas of Bolivia, Chile and Peru, who are at a high risk for unclear reasons

While 70% of patients have gallstones, the association of gallstones with cancer has never been proven to be causative. Some 80% of cases are adenocarcinoma, with the remainder being squamous or adenosquamous carcinomas.

Patients may present as:

- An incidental finding on pathological examination of a gallbladder resected for gallstones or presumed benign lesion
- Abdominal pain and anorexia with or without jaundice (due to CHD obstruction)

Cross-sectional imaging with an MRI of the abdomen, an MRCP and fluorodeoxyglucose positron emission tomography CT together with a diagnostic laparoscopy are the mainstays of disease staging. The treatment of gallbladder cancer depends on disease stage and the mode of presentation.[7] The majority of patients who present with jaundice do not have curative treatment options.

PREOPERATIVELY SUSPECTED OR CONFIRMED GALLBLADDER CARCINOMA

The patient is prepared for a radical/extended cholecystectomy. Diagnostic laparoscopy is initially performed to rule out any peritoneal, omental or surface liver deposits. If no metastatic disease is seen, radical cholecystectomy is performed either laparoscopically or by an open approach, based on the available expertise. Kocherisation of the duodenum is performed initially and any suspicious aortocaval or para-aortic lymph nodes are removed and sent for frozen section examination, as involved nodes indicate advanced disease with poor prognosis. Involved nodes imply that resection will be unsuccessful and should be abandoned. If initial node sampling is negative at frozen section, hepatoduodenal ligament lymphadenectomy is performed, commencing at the common hepatic artery lymph node and proceeding up to a level just below the hilar biliary confluence, including lymph node stations 8, 12 and 13. The cystic duct is divided and the marginal biopsy is sent for frozen section. If involved by tumour, the CBD is excised. Either a formal segment 4b and 5 resection or a wedge resection of the liver, with at least 2 cm wedge resection of the gallbladder fossa, is then performed. A lymph node yield of six or more nodes indicates adequate lymphadenectomy.

INTRAOPERATIVELY IDENTIFIED GALLBLADDER MASS

If a tumour is discovered at laparoscopic cholecystectomy, a formal operative assessment of resectability should be made. If the patient is fit for a major operation, and the disease is localised, radical cholecystectomy (2 cm wedge resection of the gallbladder bed or resection of segments 4 and 5 along with lymphadenectomy) should be considered. If the cystic duct margin is free from tumour during frozen section examination, bile duct excision is not required. It is recommended that all cholecystectomy specimens should be opened by the operating surgeons to carefully inspect the mucosal surface of the gallbladder for a mass lesion.

POSTOPERATIVELY IDENTIFIED GALLBLADDER CANCER

When the cancer is identified only by pathological examination of a resected gallbladder, the 'T' stage of the cancer is analysed. If a tumour is T1a and the cystic duct margin is free of tumour, no further operation is needed. For all lesions more than T1a, cross-sectional imaging with a CECT scan of the abdomen or an MRI of the abdomen is performed. If no metastatic disease is found, completion radical cholecystectomy is performed by resection of segment 4b/5 or a 2 cm wedge of the gallbladder bed with lymphadenectomy as described earlier. This is usually done within 4–6 weeks after the first procedure. Adjuvant chemotherapy and/or radiotherapy may be offered to patients with a good performance status.

CONGENITAL ABNORMALITIES OF THE BILIARY TREE

BILIARY ATRESIA

Biliary atresia is a neonatal obstructive cholangiopathy of unknown aetiology characterised by a fibrosclerosing obliteration of the extrahepatic bile ducts. It has been classified by the Japanese Society of Paediatric Surgeons into three types. In type 1, there is a CHD remnant and, in type 2, although no CHD, there is a left and right duct remnant. In type 3, the most common type, which occurs in 88% of cases, there is atresia of the whole of the extrahepatic ductal system.

Diagnosis

A diagnosis of biliary atresia should be considered in any neonate with conjugated hyperbilirubinaemia. Investigation is urgent, as a Kasai operation before 8 weeks of age gives the best chance of good bile flow and long-term survival. Other causes of jaundice must be excluded, and confirmatory investigations include bile duct imaging and technetium-labelled hepatobiliary excretion scans. Currently, the most reliable test for distinguishing biliary atresia from idiopathic neonatal hepatitis, aside from exploratory laparotomy, remains a percutaneous liver biopsy, assessed and reported by an experienced pathologist.

Treatment and outcome of Kasai portoenterostomy

The initial treatment is surgical reconstruction of the biliary tree. At laparotomy, a shrunken fibrotic gallbladder suggests atresia and precludes operative cholangiography. If the gallbladder is patent, it is aspirated. If bile is obtained, this suggests either a type 1 atresia or a hepatitis syndrome, and a cholangiogram should be performed. If type 1 disease is confirmed, a hepaticojejunostomy is undertaken. Types 2 and 3 disease are treated by the portoenterostomy procedure described in 1959 by Kasai and Susuki,[8] who observed bile drainage from microscopic ductules in the porta hepatis after excision of the fibrosed hepatic ducts.

In Kasai portoenterostomy, right and left branches of the hepatic artery and portal vein are isolated close to the hilum and, with sharp dissection using a scalpel, atretic scar tissue in the hilar plate is excised, layer by layer, until bile is seen oozing from multiple tiny pores in the hilar plate. A Roux-en-Y jejunal loop is anastomosed to the edges of the excised hilar plate so that bile enters the intestine.

Short-term success, which is only seen if the operation is performed before 8 weeks of life, is recognised by normalisation of the bilirubin and results in a 10-year survival of up to 90% with a native liver. If portoenterostomy fails, death before the age of 2 years is likely, without liver transplantation. Nevertheless, even with a timely Kasai operation, most patients (70–80%) eventually develop end-stage biliary cirrhosis and require a liver transplantation.[9] Biliary atresia is the most frequent cause of chronic end-stage liver disease in children and is the leading indication for liver transplantation in the paediatric population, accounting for 40–50% of all paediatric liver transplants with highly successful long-term outcomes.

CHOLEDOCHAL CYSTS

Choledochal cysts are not an isolated entity, but rather a spectrum of abnormalities in the hepatobiliary-pancreatic system. They are rare, with an estimated incidence of 1:100,000–150,000, with higher incidence in Japan and other Asian countries. About 60% are diagnosed before 10 years of age. Women are more commonly affected than men, with a ratio of 4:1. The aetiology is unknown, but an abnormal pancreaticobiliary duct junction (APBDJ) and formation of a long common channel (which is outside the duodenal wall or the sphincter complex) is frequently found. It is speculated that this results in reflux of pancreatic enzymes into the biliary tree, causing recurrent inflammatory damage, dilatation and fibrosis.

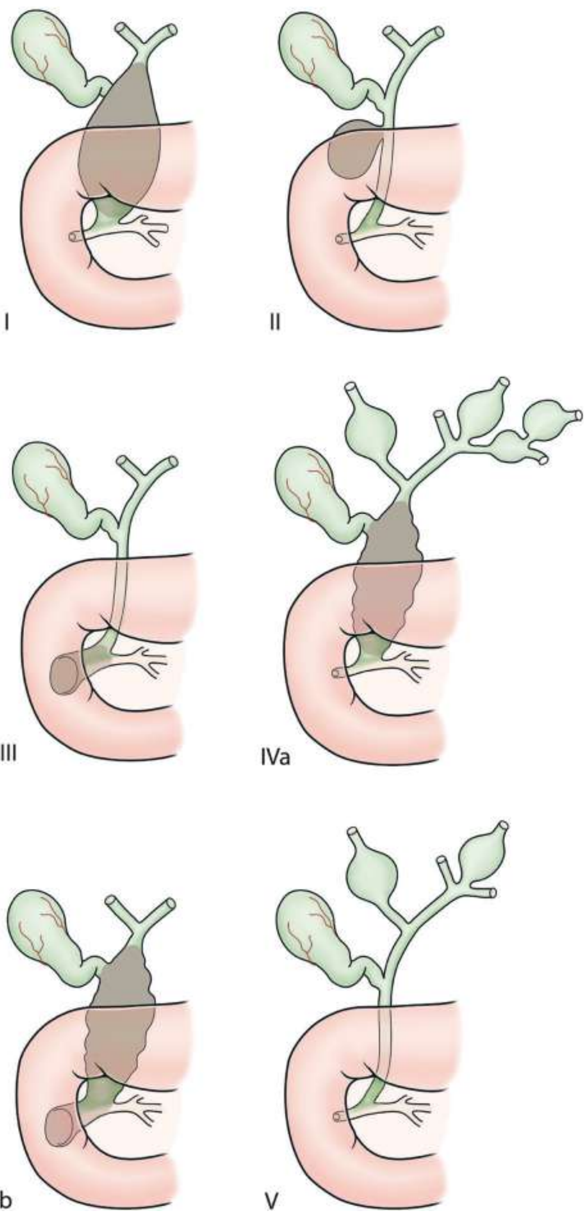
Classification

Choledochal cysts were classified in 1977 by Todani et al.[10] into five types (Figure 10.14). Several subtypes were subsequently described:

- **Type I:** most common type (80–90%); a solitary fusiform dilatation of the CBD, into which the cystic duct enters
  - **Ia:** dilatation of the extrahepatic bile duct (entire)
  - **Ib:** dilatation of the extrahepatic bile duct (focal segment)
  - **Ic:** dilatation of the CBD portion of the extrahepatic bile duct
- **Type II:** true diverticulum from the extrahepatic supraduodenal part of the bile duct
- **Type III:** dilatation of the extrahepatic bile duct within the duodenal wall (choledochocele)
- **Type IV:** second most common type
  - **IVa:** cysts involving both the intra- and extrahepatic ducts
  - **IVb:** multiple dilatations/cysts of the extrahepatic ducts only
- **Type V:** multiple dilatations/cysts of the intrahepatic ducts only (Caroli disease); associated with hepatic fibrosis

A sixth type of choledochal cyst, one involving the cystic duct alone, has been proposed. However, the authors of this chapter opine that it is not an accepted part of the Todani classification.[11]

The Komi classification classifies choledochal cysts into three types based on the type of APBDJ.



10.14 Modified Todani classification of choledochal cysts. ⏎

Presentation and treatment

Choledochal cysts may present at any age, starting from the neonatal period. Clinical features include recurrent abdominal pain, jaundice, recurrent cholangitis, acute or chronic pancreatitis and, in children, a right hypochondrial mass. Emergency presentation with cyst rupture is a recognised complication in infants. If choledochal cysts are left untreated, liver abscesses, cirrhosis, portal hypertension and cholangiocarcinoma, involving any part of the biliary tree or gallbladder cancer, can result.[12] The diagnosis is usually made by ultrasound, but definition of the anatomy of the biliary tree is best done using MRCP imaging. Treatment is surgical, based on cyst type and associated hepatobiliary pathology. In principle, the extrahepatic biliary tree should be excised and bile flow re-established by a biliary-enteric anastomosis. Type III choledochal cysts can be followed up without an operation. For type IV choledochal cyst, we recommend excision of the extrahepatic biliary tree with biliary-enteric anastomosis and follow-up of the intrahepatic cysts. Others advocate liver resection to resect the intrahepatic part. Patients with Caroli's disease (type V) may require liver transplantation if they present with portal hypertension (see Chapter 12).

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11 Surgery of the pancreas and spleen

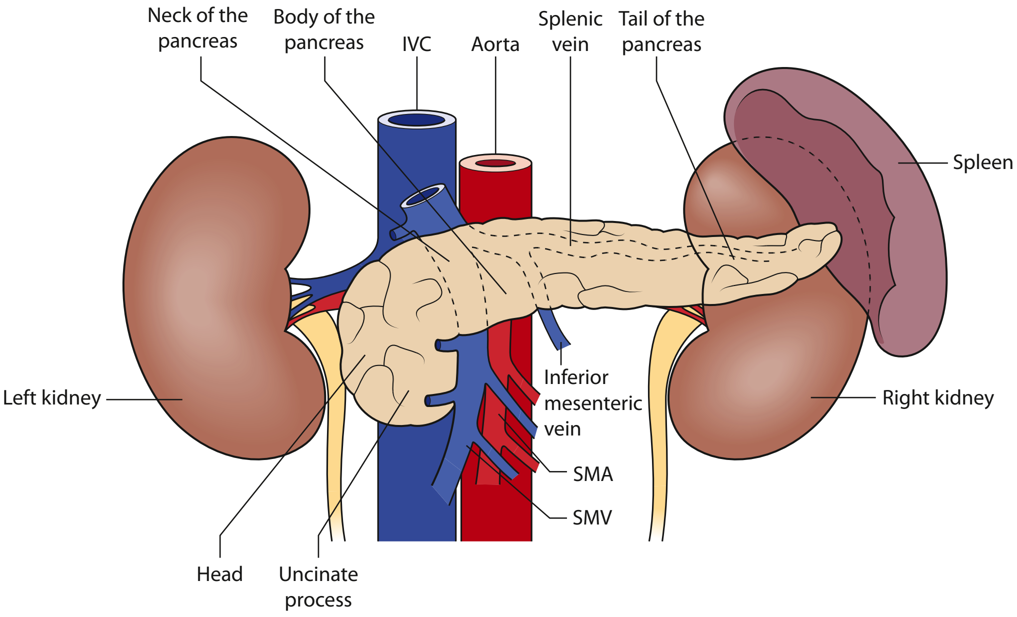
Nalini Kanta Ghosh, Rajneesh Kumar Singh and Shaleen Agarwal

THE PANCREAS: ANATOMY, EMBRYOLOGY AND PHYSIOLOGY

GROSS ANATOMY OF THE PANCREAS

The pancreas is a retroperitoneal organ that can be divided into the head, uncinate process, neck, body and tail, although there is no precise universally agreed demarcation between these segments. The head of the pancreas sits in the duodenal curvature anterior to the inferior vena cava (IVC); the neck overlies the superior mesenteric vein (SMV) and superior mesenteric artery (SMA), which form a posterior groove in the pancreas; the body lies to the left of the neck; the tail is to the left of the aorta, nestled in the hilum of the spleen. The Union for International Cancer Control's tumour, nodes and metastases (TNM) classification (seventh edition) categorising pancreatic tumours uses the left border of the SMV as the division between the head and body for pancreatic tumours. The uncinate is considered part of the head, and the inferior-medial border has variable extension behind the mesenteric vessels.

The important vascular relationships of the pancreas are the IVC, the aorta and its branches, the portal vein (PV), the splenic artery, the splenic vein and the SMV. Posteriorly, the pancreas overlies the IVC and the aorta and its branches, namely the coeliac axis and the mesenteric vessels. The PV is also an important structure behind the pancreas and is formed by the confluence of the splenic vein and the SMV, behind the neck of pancreas; the splenic artery has a tortuous course along the superior border while the splenic vein is posterior to the body; the superior mesenteric vessels course anterior to the uncinate process and, hence, any accessory hepatic artery arising



11.1 Posterior relationship of the pancreas. ⏎

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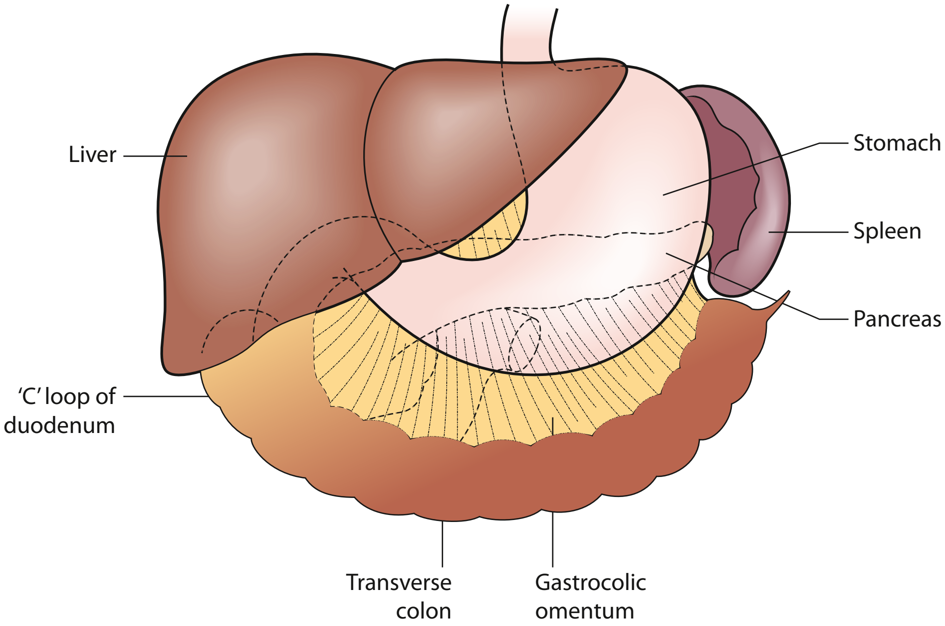


11.2 Anterior relationship of the pancreas. ⏎

from it is closely related to the uncinate process and head, as it runs upwards (Figure 11.1).

Anterior to the pancreas is the stomach, lesser sac (omental bursa) and transverse mesocolon (Figure 11.2). The posterior surface of the pancreas is related to the IVC, aorta, PV, splenic vein, left renal vessels, left adrenal gland and left kidney. During blunt abdominal trauma, the neck of the pancreas is prone to injury due to severe compression against the vertebral body posteriorly.

DUCTAL SYSTEM OF THE PANCREAS

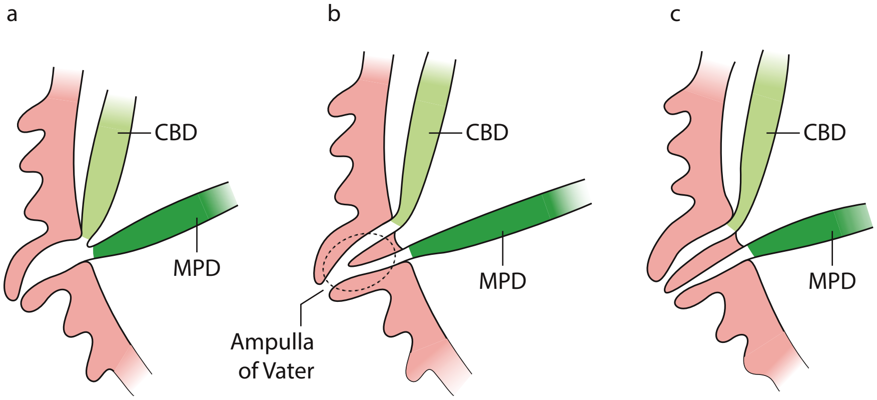
The main pancreatic duct (MPD), or duct of Wirsung, runs from the tail to the head of the pancreas. In the head, the duct of Wirsung runs downwards, and parallel, to the common bile duct (CBD) for approximately 2 cm and joins the CBD within the sphincter of Oddi in 70–85% of patients; it enters the duodenum independently in 10–13% of patients and is replaced by the duct of Santorini in 2% of patients (Figure 11.3). The pancreatic duct opens into the second part of the duodenum at the major duodenal papilla. At the termination into the duodenum is the sphincter of Oddi, a smooth muscle sphincter that controls the flow of secretions and also prevents the reflux of enteral content. The diameter of the pancreatic duct is, on average, 4 mm in the head of the pancreas, 3 mm in the body and 2 mm in the tail.

ANATOMY OF THE AMPULLA OF VATER

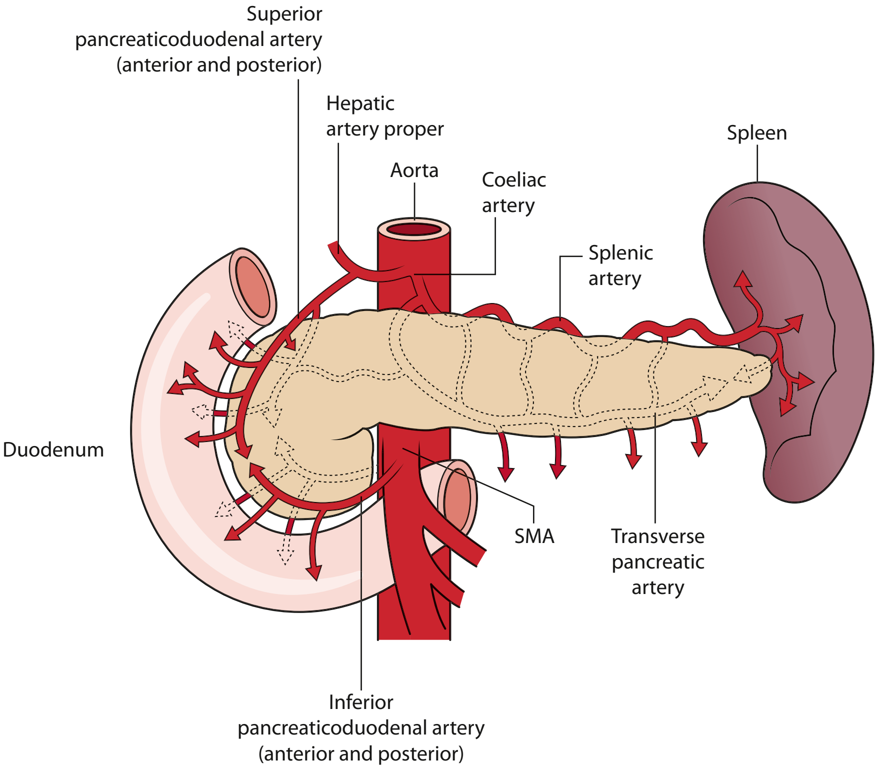
The ampulla of Vater (i.e. the hepatopancreatic ampulla) corresponds anatomically with the dilated junction of the CBD and the MPD of Wirsung before their combined opening into the duodenum. From the surgical viewpoint, the ampulla of Vater constitutes the junction of the biliary, pancreatic and digestive tracts, and the ampulla corresponds to a functional region that is surrounded by the sphincteric system of Oddi. The periampullary region, centred on the ampulla of Vater, is the site of various tumours, often with a life-threatening prognosis and needing surgical treatment.

BLOOD SUPPLY

The head and uncinate process receive their blood supply from the superior pancreaticoduodenal artery (SPDA) and the inferior pancreaticoduodenal artery (IPDA), which each contribute to the anterior and posterior pancreaticoduodenal arcades. The SPDA is a branch of the gastroduodenal artery (GDA), which in turn derives from the common hepatic artery (CHA), a branch of the coeliac trunk. The IPDA arises from the SMA. The body and tail of the pancreas receive their blood supply from numerous branches of the splenic artery, and the neck is a vascular watershed area between the head and the body/tail. The venous drainage of the head is via the superior mesenteric branches of the PV and the remainder of the pancreas is drained by short, fragile branches of the splenic vein (Figures 11.4 and 11.5).


a
b
c
CBD
MPD
CBD
MPD
Ampulla of Vater
CBD
MPD

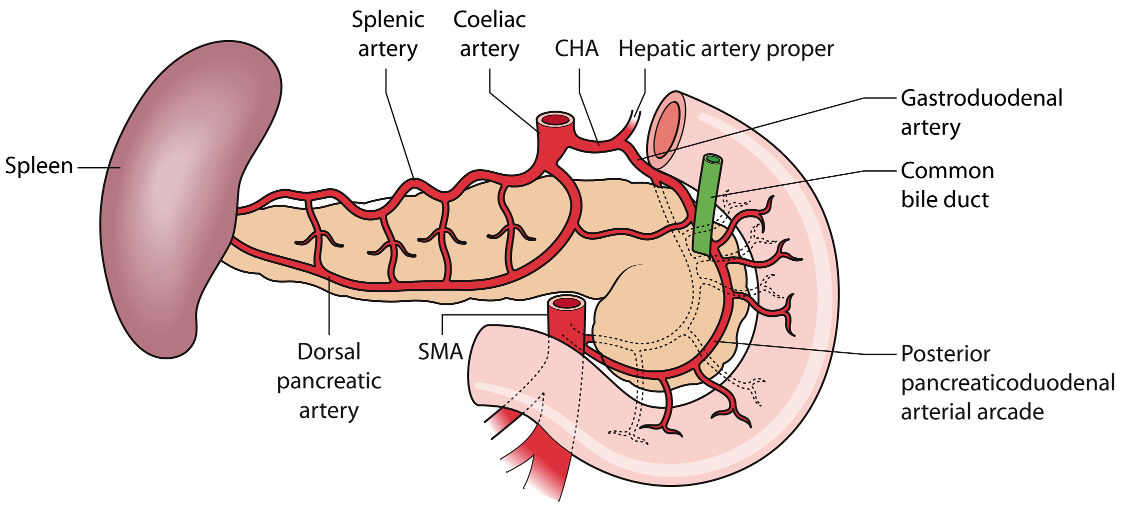
11.3 Ductal anatomy of the ampulla of Vater. (a) Common channel formed by the union of the CBD and the MPD. (b) No common channel, but a single common opening of the CBD and MPD. (c) No common channel, and separate openings of the CBD and the MPD. ⏎


Superior pancreaticoduodenal artery (anterior and posterior)
Hepatic artery proper
Aorta
Coeliac artery
Spleen
Splenic artery
Duodenum
SMA
Transverse pancreatic artery
Inferior pancreaticoduodenal artery (anterior and posterior)

11.4 Arterial anatomy of the pancreas (anterior view). ⏎

KEY CLINICAL POINTS

- Duodenal preservation is challenging during pancreatic head resection due to shared blood supply.
- Injury to the anterior branch of the SPDA can occur during lateral pancreaticojejunostomy and Frey's procedure.
- The anterior surface of the PV is devoid of branches, which facilitates safe retropancreatic tunnel dissection.


Splenic artery
Coeliac artery
CHA
Hepatic artery proper
Gastroduodenal artery
Common bile duct
Spleen
Posterior pancreaticoduodenal arterial arcade
Dorsal pancreatic artery
SMA

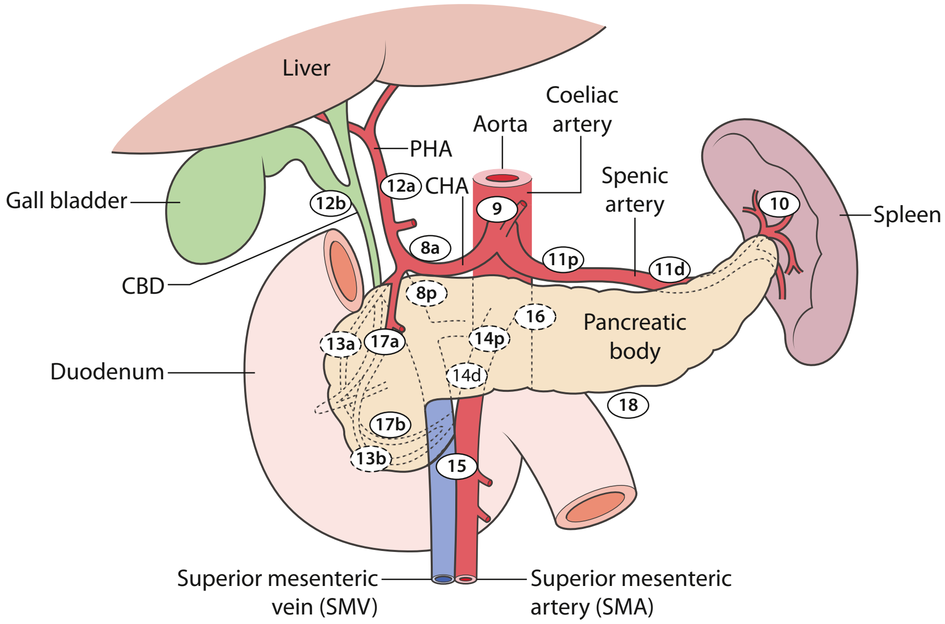
11.5 Arterial anatomy of the pancreas (posterior view). ⏎

LYMPHATIC DRAINAGE

The pancreas is drained by a rich lymphatic network that follows that of the arterial blood supply. Some authors have described five lymph node groups draining the pancreas (i.e. superior, inferior, anterior, posterior and splenic). The Japanese system of classification of pancreatic cancer has been adopted by several expert consensus groups (Figure 11.6). In the Japanese system, the lymph node stations around the pancreas have been numbered and defined carefully. The reader is advised to read this classification for a detailed review of the nodal stations draining the pancreas. Accordingly, the terms 'standard lymphadenectomy' and 'extended/radical lymphadenectomy' have been crystalised depending on the stations of nodes removed at surgery.

KEY CLINICAL POINTS

- Pancreatic cancers spread rapidly due to the rich lymphatic and venous drainage.
- No lymphatic communication exists between the pancreas and the greater and lesser curvature of the stomach. Hence, omentectomy is not routinely necessary in patients with pancreatic cancer.


Liver
Coeliac artery
Aorta
PHA
Spenic artery
Gall bladder
12b
12a
CHA
9
10
Spleen
8a
11p
11d
CBD
8p
16
Pancreatic body
13a
17a
14p
Duodenum
14d
18
17b
13b
15
Superior mesenteric vein (SMV)
Superior mesenteric artery (SMA)

11.6 Peripancreatic lymph node stations. ⏎

PERIPANCREATIC NERVES

The pancreas receives rich autonomic innervations from both the sympathetic (splanchnic nerves) and parasympathetic nervous system (vagus nerve). Most nerves follow the blood vessels. Both sympathetic and parasympathetic nerves carry visceral afferent pain fibres that pass cranially through the greater splanchnic nerves, and an awareness of this anatomy is important to understand the pain of chronic pancreatitis and pancreatic cancer. Hence, splanchnic nerve and coeliac plexus blockade can be used to ameliorate pain in pancreatic diseases. Perineural invasion in a patient with pancreatic cancer is also a marker of poor prognosis. For a detailed review of peripancreatic nerve plexi, the reader is referred to the Japanese classifications. However, routine nerve plexus dissection has not been recommended due to the absence of demonstrable benefit (*Clinical Practice Guidelines for Pancreatic Cancer 2022* from the Japan Pancreas Society).

MESOPANCREAS

Conceptually similar to the mesorectum, the mesopancreas was described to explain, and try to reduce, the locoregional relapse of pancreatic cancer. Previously, the mesopancreas was described as a borderless fibro-fatty tissue structure containing nerve fibres, blood vessels and lymphatic tissue, extending posteriorly from the pancreatic head and uncinate to the SMA and SMV, and to the left of the SMA to the IVC, the aortocaval groove and the aorta. More recent research has suggested that it is consistent with the head of the pancreas nerve plexi. Presently, there is no clear consensus regarding the nomenclature or resection of the mesopancreas.

EMBRYOLOGY OF THE PANCREAS

Embryologically, the pancreas develops from two buds: a ventral bud and a dorsal bud originating from the endodermal lining of the duodenum. During the second month of development, the stomach rotates and the duodenum becomes C-shaped and the ventral pancreatic bud migrates dorsally. The dorsal pancreatic bud develops into the superior part of the pancreatic head, the body and the tail. The ventral bud develops into the inferior half of the pancreatic head and the uncinate process. The dorsal pancreatic bud drains through the MPD of Wirsung and is initially connected to the minor papilla. After the duodenal rotation, the duct of Wirsung drains through the major papilla. In 25% of patients, the proximal part of the dorsal duct persists as the accessory duct of Santorini, which enters the duodenum through the minor papilla. Failure of fusion of the ductal systems results in drainage of the majority of pancreatic secretions of the superior part of the head, body and tail through the minor papilla, and this is known as pancreatic divisum. Another rare congenital anomaly is the annular pancreas, wherein the pancreatic tissue forms an incomplete, or complete, ring around the second part of the duodenum. An annular pancreas can lead to obstructive symptoms.

KEY CLINICAL POINTS

- Tumours arising from the ventral and dorsal pancreas have different patterns of lymph node spread and prognosis.
- Tumours of the dorsal pancreas spread more frequently to the hepatoduodenal ligament and have a worse prognosis than the tumours of the ventral pancreas, which has a propensity to spread to the SMA group of lymph nodes.

HISTOLOGY

The pancreas is a composite gland with both exocrine and endocrine components. The exocrine component forms the bulk of the gland, with the serous acinar cells comprising 80% of the gland volume. In contrast, the endocrine component within the islets of Langerhans comprises a mere 2% of the gland structure. The remaining 18% comprises ducts, nerves, vessels and connective tissue.

PANCREATIC PHYSIOLOGY

The pancreas has both exocrine and endocrine functions. The exocrine pancreas consists of acini and a ductal network that secrete enzymes and bicarbonate-rich fluid into the duodenum for digestion. The hormonal stimulus for exocrine secretion is predominantly in the form of cholecystokinin and secretin, which promote enzyme and bicarbonate/fluid secretion, respectively, in response to fat/amino acids or acid in the duodenum, respectively. Pancreatic exocrine enzymes are activated only after coming into contact with the duodenal contents. Conditions such as acute pancreatitis may result in intrapancreatic enzyme activation, with devastating consequences. The endocrine component within the islets of Langerhans includes the alpha-cells, which secrete glucagon; the beta-cells, which secrete insulin in response to a rise in blood glucose; and a host of endocrine cells that produce other hormones including somatostatin, pancreatic polypeptide and ghrelin.

GENERAL PRINCIPLES OF PANCREATIC SURGERY

Surgery of the pancreas is a complex undertaking and requires specialised knowledge of anatomy, physiology and pathology. Preoperative and intraoperative decision-making, technical operative skill and management of postoperative complications are all of key importance. These factors, as well as recent advances in minimally invasive surgery, have led to the centralisation of surgery to high-volume specialised centres with many benefits compared with low-volume centres. However, general surgeons need to have experience with pancreatic resections, as they may need to treat pancreatic trauma and may encounter the pancreas during surgery for the stomach, colon, aorta, spleen, left kidney, adrenal gland, etc.

INTRAOPERATIVE IDENTIFICATION OF THE PANCREAS

Normal pancreas can be identified by its slightly pinkish colour (often said to be salmon pink), which appears distinct from the surrounding yellow fat of the retroperitoneum after opening the gastrocolic omentum. Palpation of the gland provides information about the consistency of the pancreas (soft, firm or hard). A surgeon should try and identify the pancreas during surgery in the vicinity of the pancreas (i.e. during the Kocher manoeuvre, gastrectomy, choledochal cyst excision, splenectomy, nephrectomy, adrenalectomy and colonic mobilisation).

HAEMORRHAGE AND LACERATIONS

The pancreas is a well-vascularised organ and is prone to bleeding and lacerations due to trauma and surgery. The soft pancreas is especially prone to bleeding from small vessels due to inadvertent shearing and lacerations caused during dissection. Bleeding points may be secured with one of many energy devices or haemostatic materials. However, the best method is to use fine monofilament sutures to secure the bleeding tissues, as post-surgery pancreatic enzyme leak can cause secondary haemorrhage. Pancreatic lacerations without significant ductal disruptions may be left alone, or approximated with fine sutures, with placement of drains. Larger lacerations involving the MPD need some form of pancreatic resection. Although resection of the tail, or distal body, may be possible by a general surgeon, more extensive resections need specialised advice and help. The remnant stump after resection should be secured with monofilament sutures or by mechanical stapling, preferably with prior suturing of the pancreatic duct, if the duct can be identified. Leaks are common (20–25%); hence, effective drainage of the region is mandatory.

KEY CLINICAL POINTS

- Knowledge of the anatomy, physiology and pathology of the pancreas is essential to make complex pancreatic surgery easier.
- Intraoperative identification of the pancreas is necessary to prevent unwanted pancreatic injury.
- In a fibrotic pancreas, palpation to locate the pancreatic duct may be arduous.
- Meticulous haemostasis is paramount to prevent complications.
- Drainage of pancreatic collections is necessary to prevent infectious and haemorrhagic complications.

DRAINS AND FISTULAE AFTER PANCREATIC SURGERY

Pancreatic surgery is notorious for the high incidence of pancreatic leaks and resultant complications, such as abscesses, haemorrhage and fistulae. Intuitively, effective drainage is routinely recommended to reduce these complications. Recent studies have indicated that a selective policy of drain placement may be useful to avoid drain-related morbidity. In deliberating the use of drains, several factors need to be considered, including the risk of pancreatic leak, surgical experience, distal versus proximal pancreatic resections and the ability to perform close monitoring and early intervention if needed. In the event of uncertainty, it may be prudent to place drains and remove them as early as possible. On the other end of the scale, pancreatic fistulae, once formed, need continual drainage by patent, optimally positioned drainage. As the fistula output reduces, the drain may be shortened and placed in a drainage bag, or stoma appliance, with frequent follow-up in the outpatient clinic. In the event of a long-standing fistula, along with other ancillary measures such as dietary management and drugs (e.g. somatostatin analogues), surgeons may need to consider endoscopic stent placement or, uncommonly, surgical resection of the remanent pancreas.

PANCREATIC NEOPLASMS

Primary benign and malignant neoplasms of the pancreas can arise from various histological elements of the pancreas, including the pancreatic duct, endocrine cells, exocrine cells and mesenchymal cells. The distinction is important before making a surgical decision, but not always possible. Extra-pancreatic malignancies rarely metastasise to the pancreas.

PANCREATIC DUCTAL ADENOCARCINOMA

Pancreatic ductal adenocarcinoma (PDAC) is the most common and highly aggressive malignant neoplasm of the pancreas. Only about 15–20% of patients have resectable disease at presentation. The location is in the head of the pancreas in about two-thirds of patients and, hence, the common clinical presentation is progressive, obstructive, jaundice and, often, initially painless, but is accompanied by pain in more advanced tumours. Pain radiating to the back is typically present in locally advanced tumours of the pancreatic body, along with anorexia and weight loss. Duodenal involvement and obstruction lead to post-prandial upper abdominal fullness and vomiting. Uncommon presentations include new-onset diabetes or worsening of glucose tolerance, a palpable abdominal mass, severe malignant cachexia and ascites.

PERIAMPULLARY NEOPLASMS

Periampullary neoplasms are a group of tumours located within 2 cm of the ampulla of Vater (e.g. pancreatic adenocarcinoma, cholangiocarcinoma, duodenal adenocarcinoma and ampullary adenocarcinoma). Periampullary tumours are considered together due to their similar clinical presentation and surgical treatment (i.e. pancreaticoduodenectomy [PD]). However, tumour type is also an important determinant of prognosis.

CYSTIC NEOPLASMS OF THE PANCREAS

About 1–10% of pancreatic cystic lesions are cystic neoplasms, usually with uncertain malignant potential. The diagnosis usually hinges upon characteristics defined by contrast-enhanced computed tomography (CT) scans. In the case of persistent uncertainty about the diagnosis and malignant potential, more information may be obtained from magnetic resonance imaging (MRI)/magnetic resonance cholangiopancreatography (MRCP), endoscopic ultrasound (EUS) examination, serum tumour markers and cyst fluid analysis. Serous cystic neoplasms are usually benign and need no treatment if asymptomatic. Mucinous cystic neoplasms are macrocystic cystic lesions usually located in the pancreatic body and tail and are more common in female patients. The risk of invasive malignancy ranges from 10% to 50% and the indication for surgery is based on this risk assessment. Some would advocate resection of all mucinous cystic neoplasms in view of this uncertainty in assessing the risk of malignancy. More recent guidelines (2018 European guideline) have recommended resection for cysts >4 cm, cysts with enhanced mural nodules or symptomatic cysts. Patients with asymptomatic cysts <4 cm are recommended to have surveillance. Solid pseudopapillary tumours are lesions seen mostly in young females. They have significant malignant potential, and a surgical resection is indicated.

Intraductal papillary mucinous neoplasms (IPMNs) arise within the MPD, or branch ducts, causing ductal dilatation with mucin and are classified as main duct, branch duct or mixed type based on the extent of involvement. Main duct IPMNs have the greatest risk of malignancy (approximately 60%) and branch duct IPMNs are the least aggressive (12–30% risk of malignancy). Branch duct IPMNs are usually diagnosed as a single or multiseptated lesion communicating with the undilated main duct. The need for surgical resection is tailored to address a neoplasm with high-risk features for malignant transformation (i.e. the presence of enhancing mural nodules [>5 mm], a dilated MPD [10 mm or more] and obstructive jaundice). Considered balanced decision-making is needed to proceed to resection in neoplasms with ‘worrisome’ features such as lesions of over 3 cm in diameter, enhancing mural nodules >5 mm, thickened enhanced cyst walls, an MPD size of 5–9 mm, an abrupt change in the MPD calibre with distal pancreatic atrophy, lymphadenopathy, an elevated serum level of carbohydrate antigen (CA)19-9 and a rapid rate of cyst growth >5 mm/2 years. The goal of resection is to achieve a margin free of high-grade dysplasia with an acceptable risk and morbidity. The extent of resection for main duct IPMNs can therefore be difficult to determine when considering these factors, and a total pancreatectomy may be required.

PANCREATIC NEUROENDOCRINE TUMOURS

Pancreatic neuroendocrine tumours (PNETs) arise from the endocrine cells of the islets of Langerhans. These tumours can be associated with some of the familial syndromes, such as MEN1, VHL, NF1 and TS. Clinically, PNETs can be either functional tumours or, more commonly (75%), non-functional tumours. The presentation of non-functional tumours is usually due to mass effect (pain, compression, etc.) and not due to the production of specific hormones. Functional PNETs usually present earlier due to hormone production and have a better prognosis. Insulinomas secrete insulin and/or pro-insulin, which produce hypoglycaemia and a characteristic Whipple's triad (plasma glucose less than 40 mg/dL, neuroglycopenic symptoms and resolution of symptoms with administration of glucose or food). The diagnosis is confirmed with clinical features of the classical Whipple's triad on 72-hour fasting and imaging demonstration of a neuroendocrine tumour. Sometimes, these lesions are too small to be demonstrated on CT or MRI scans and require arterial stimulation venous sampling or intraoperative ultrasonography.

Gastrinomas are gastrin-secreting neuroendocrine tumours of the pancreas. They present with gastric acid hypersecretion, recurrent peptic ulcers, diarrhoea and reflux oesophagitis. Tumours associated with MEN1 syndrome tend to be small and multiple and are more likely to arise from the duodenum. Most gastrinomas have malignant potential and should be treated as such. The diagnosis is made with a fasting gastrin level >10 times normal and a gastric pH <2. In equivocal cases, secretin or glucagon stimulation is needed. The majority of gastrinomas arise from the 'gastrinoma triangle' bounded by the cystic duct: the CBD junction, the junction of the second and third parts of the duodenum, and the neck of the pancreas.

PNETs are best evaluated by contrast-enhanced CT scan and serum markers in the case of functional tumours. If needed, further characterisation may need MRI and EUS/EUS-guided fine needle aspiration cytology (FNAC). Somatostatin receptor imaging with 68-gallium functional positron emission tomography (PET) scans and 18-fluorodeoxyglucose PET scans are useful in working up patients for metastatic disease. Surgical resection and lymphadenectomy are the main treatment modalities to achieve loco-regional control of a PNET. In cases of metastatic disease, partial or complete metastasectomy may be considered for symptomatic control. Pancreas-preserving resections such as enucleation can be attempted in benign tumours including small insulinomas that are away from the MPD. Management of asymptomatic, small, non-functional PNETs is still debatable. In these cases, the decision-making depends on the grade of the tumour, the size of the tumour, the risk of surgery and the patient's expectations. Some guidelines suggest active surveillance for tumours <2 cm, while others reserve surveillance for tumours <1 cm.

PANCREATICODUODENECTOMY

The main indications for PD are as follows:

- Resectable periampullary carcinoma
- Chronic pancreatitis with a pancreatic head mass that causes suspicion of malignancy
- Benign high-risk lesions of the pancreatic head
- Grade V pancreatic head trauma

Preoperative preparation

The initial patient workup is for diagnosis, staging and establishing the indication for PD. Thereafter, the patient needs to be evaluated to assess their fitness for surgery. Risk optimisation includes assessment and management of comorbidities and prehabilitation. Prehabilitation aims to improve the functional condition of the patient prior to surgery, in order to enhance postoperative recovery. It includes medical optimisation (smoking cessation, reduction in alcohol intake, weight optimisation, management of anaemia and optimisation of comorbidities), physical exercise, nutritional optimisation and psychological support. A pancreatic protocol CT scan is usually performed when considering pancreatic surgery. PDAC can then be classified as resectable, borderline resectable or unresectable, depending on the vascular (artery and vein) involvement. Patients with a resectable PDAC of the head of the pancreas may be considered for upfront surgery. In cases of borderline resectable pancreatic cancer, neoadjuvant chemotherapy followed by surgery has shown promising results. In cases of unresectable lesions, palliative treatment may be provided.

Preoperative biliary drainage

Obstructive jaundice is often present in patients with PDAC, or periampullary carcinoma, and is often considered to be associated with increased postoperative morbidity. Preoperative biliary drainage (PBD) (usually by endoscopic retrograde cholangiopancreatography [ERCP]) may be considered to alleviate obstructive jaundice in those with cholangitis, intractable pruritus, significant nutritional deficiency and coagulopathy, as well as in those who need optimisation, need neoadjuvant therapy or have other reasons for delayed surgery. It has been hypothesised that the increased infective postoperative complications (37% vs 47%: DROP trial) related to PBD may offset the benefits of PBD. Therefore, according to recent research, PBD should not be considered just to alleviate jaundice, in the absence of any other firm indication for PBD, as mentioned previously. After PBD, surgery may be delayed for about 3–4 weeks, depending on the indication for PBD in a given patient, to gain maximum benefit.

Preoperative tissue diagnosis

Preoperative tissue diagnosis is not necessary in a surgically fit patient with a clear clinical diagnosis and resectable lesion on imaging. It is essential in patients with unresectable or borderline-resectable lesions who are being considered for chemotherapy. Preoperative biopsy may also be considered in high-risk patients who are being considered for surgery. However, it must be understood that biopsy or fine needle aspiration cytology may be falsely negative and should not be a contraindication for surgery, if otherwise clinically indicated. A small proportion (10%) of patients turn out to have benign pathology after PD and should be counselled upfront with regard to this possibility.

OPERATIVE PROCEDURE

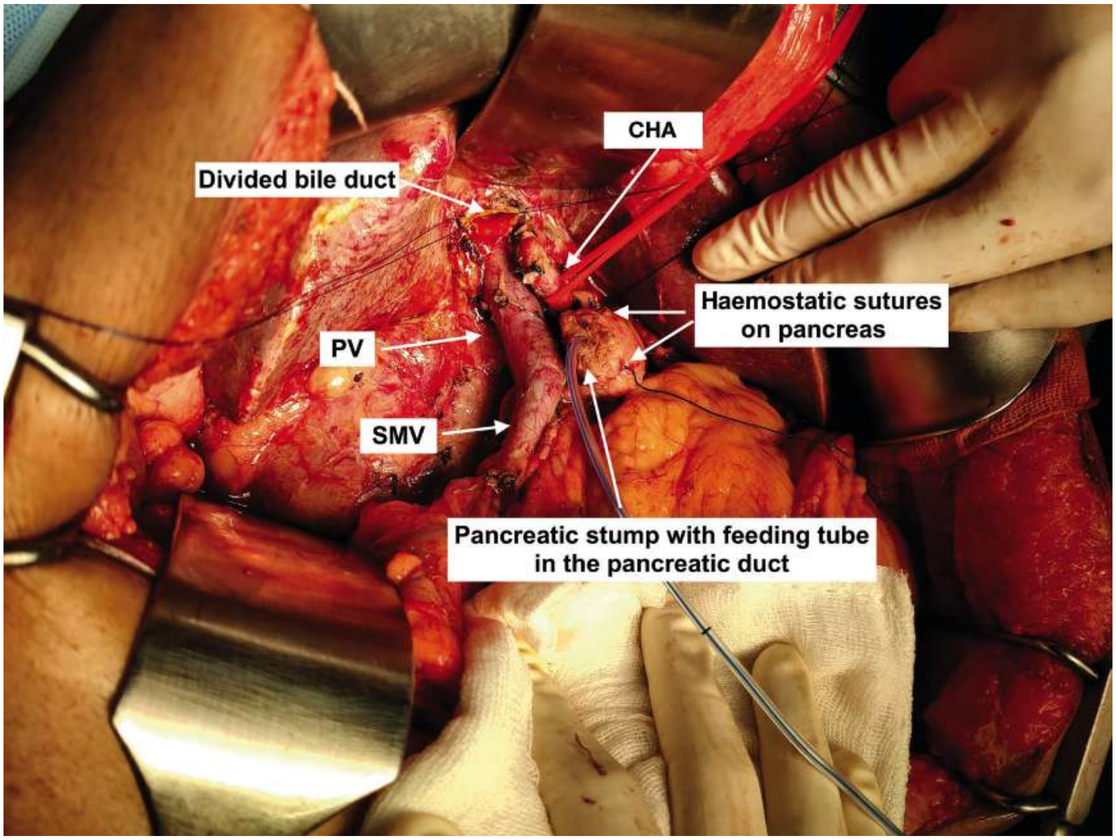
PD is carried out in the supine position under a combination of general and epidural anaesthesia, and the epidural component is also useful for postoperative pain control. Staging laparoscopy should be carried out to screen for metastatic disease in patients with aggressive high-risk tumours (e.g. large tumours, high serum tumour markers, poorly differentiated tumours and regional lymph nodes) (2023 National Comprehensive Cancer Network guidelines).

The abdominal incision is usually a rooftop (bilateral subcostal) or midline incision (in patients with a narrow costal angle). After good exposure of the abdominal cavity, using appropriate retractors, a thorough exploration of the abdomen is carried out to assess for occult metastastatic disease, especially on the liver surface, omentum, peritoneal surfaces and pelvis. This includes frozen-section pathology examination of aortocaval and para-aortic nodes, if any. Any metastatic disease would be a contraindication to a major resection. Thereafter, the hepatic flexure of the colon is mobilised downwards, together with division of the right half of the gastrocolic omentum, using energy sources (e.g. ultrasonic shears), to expose the duodenum and head of the pancreas, as well as to enter the lesser sac. Careful attention to detail should prevent inadvertent devascularisation of the omentum. An extended Kocher manoeuvre is then carried out to mobilise the duodenum off the retroperitoneum until the left renal vein is visualised, taking care to protect retroperitoneal structures. In this manoeuvre, as the second and third parts of the duodenum are mobilised, the SMV is identified at the mesenteric base. Care should be taken to ligate, and divide, the right gastroepiploic vein and/or Henle's trunk before the transverse colon can be retracted firmly downwards to expose the head and neck of the pancreas. Surgeons need to pay attention to numerous variations in the small veins in this region to prevent troublesome haemorrhage. Thereafter, division of any lesser sac adhesions and cranial retraction of the stomach ensures exposure of the proximal body of the pancreas. The small venous branches tethering the SMV to the pancreas are divided, and the inferior border of the neck of the pancreas is exposed. Meticulous dissection between the neck of the pancreas and the SMV opens up the retropancreatic tunnel, as there are no veins traversing between the neck of the pancreas and the posteriorly placed SMV/PV.

The artery-first approach is based on the understanding that early confirmation of suspicious arterial invasion can avoid further unnecessary dissection. There are several approaches described to carry out the artery-first dissection. The common points in these descriptions are the exposure of the artery in the mesenteric base to the left of the SMV and the exposure of the SMA near the origin, posterior to the mobilised pancreatic head. Various approaches may be chosen, depending on the location of the tumour, to dissect the right SMA border off the tumour.

Hepatoduodenal ligament (HDL) dissection is performed after retracting the stomach/duodenum caudally and the liver cranially. This is best done from left to right after division of the flimsy lesser omentum, along the superior border of the pancreas, sweeping nodes off the CHA. The right gastric artery is often encountered and may be divided to gain exposure of the GDA in the HDL.

Prior to GDA ligation, a test clamping is performed with a vascular clamp to ensure good pulsation in the proper hepatic artery in the HDL. In the presence of coeliac artery stenosis, the majority of blood flow to the liver is derived from the SMA via the GDA. Hence, PD is contraindicated in coeliac artery stenosis unless stenosis is treated beforehand. Furthermore, the GDA may be an important source of post-PD haemorrhage. To this effect, certain precautions may be taken during GDA ligation, including double ligation, leaving a stump of at least 5–10 mm, and marking with a radio-opaque vascular clip. The next step is fundus-first dissection of the gallbladder, division of the cystic artery and retraction of the dissected gallbladder medially to expose the lateral border of the HDL. An intraoperative exploration is then performed for pulsations of the accessory, or replaced, right hepatic artery postero-lateral to the bile duct and PV. If found, this artery needs to be carefully preserved while dissecting the HDL. The bile duct is encircled and divided, preferably above the level of the cystic duct, with attention to the hepatic artery and its branches. This usually exposes the PV, and all lymphatic tissue in the HDL is swept down *en bloc*, while avoiding injury to the arteries and PV. A small vascular clamp on the proximal bile duct stump prevents continuous bile leak, and ligation of the distal stump avoids the same. Bile from the bile duct and any biliary stents encountered should be sent for culture and sensitivity testing.


CHA
Divided bile duct
Haemostatic sutures on pancreas
PV
SMV
Pancreatic stump with feeding tube in the pancreatic duct

11.7 Operative picture post PD. ⏎

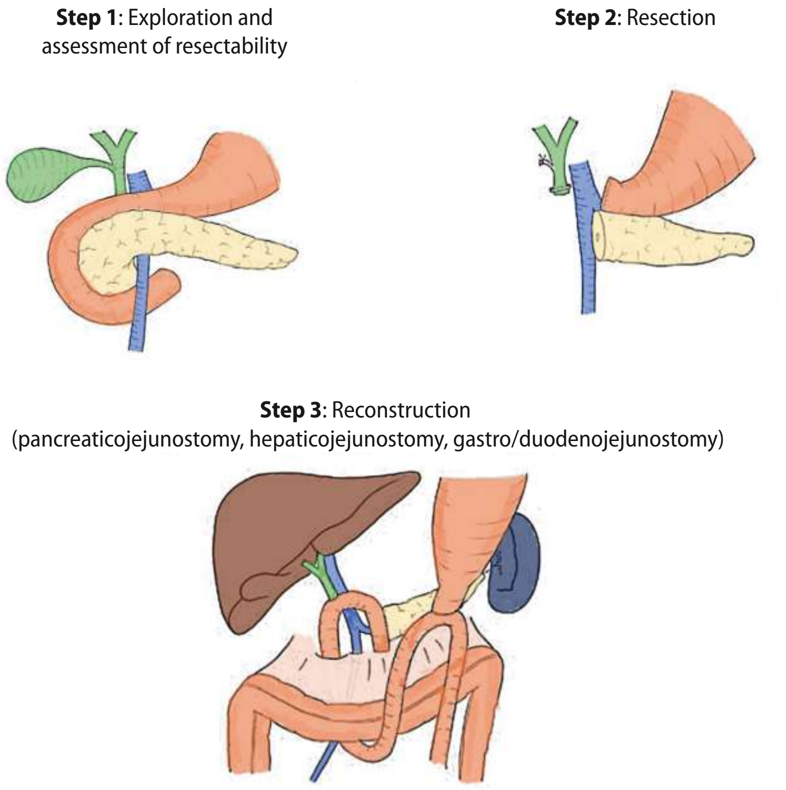
The retropancreatic tunnel is completed after the PV is laid bare in the HDL and the pancreatic neck is encircled with a tape, ready to be divided. If there is difficulty in completing the tunnel, suspicion is raised about SMV/PV involvement by the tumour, and this needs to be tackled with control over the PV/SMV after dividing the neck of the pancreas. Venous resection, and reconstruction, in such cases is best planned preoperatively with information from a good-quality CT scan.

The site of proximal gut division depends on the type of PD. Classically, the distal antrum of the stomach is resected, and the first part of the duodenum is preserved in the pylorus-preserving variation of PD. In this respect, several modifications of PD have been described. However, in randomised trials, none has shown consistent superiority. After mobilisation of the duodenojejnual flexure, the jejunum is divided 5–10 cm beyond it. Jejunal division may be performed either in the infracolic compartment or after delivering the jejunum under the mesenteric base into the supracolic compartment.

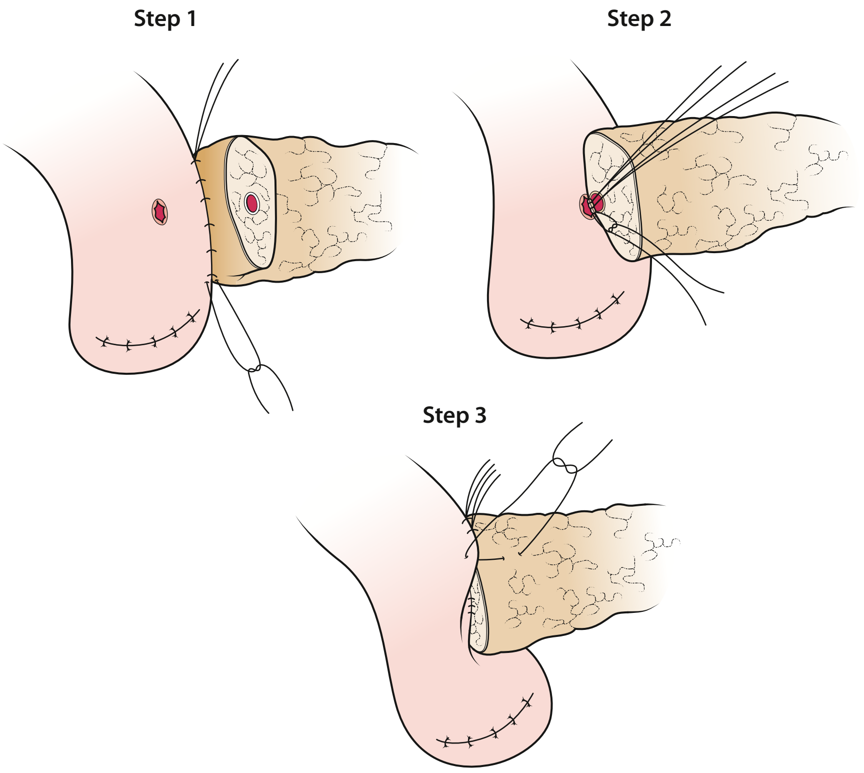
The pancreatic neck is carefully divided with an energy device to achieve haemostasis while using sharp division (e.g. knife or scissors) of the pancreatic duct. The last part of the resection is the division of the uncinate process away from the SMV/PV and the right border of the SMA, including *en bloc* removal of the lympho-vascular and neural tissue. During uncinate process dissection, any aberrant right hepatic artery may be encountered, arising proximal to the SMA, and needs to be preserved in this step. Standard lymphadenectomy is performed, as extended lymphadenectomy has been shown to have higher morbidity (43% vs 29%, $p = 0.01$) with no significant difference in the median overall survival (Figure 11.7).

After removal of the specimen, meticulous haemostasis must be achieved. Preferably, frozen-section examination of the pancreatic neck and the bile duct margins should be performed to assess whether further tissue resection is required.

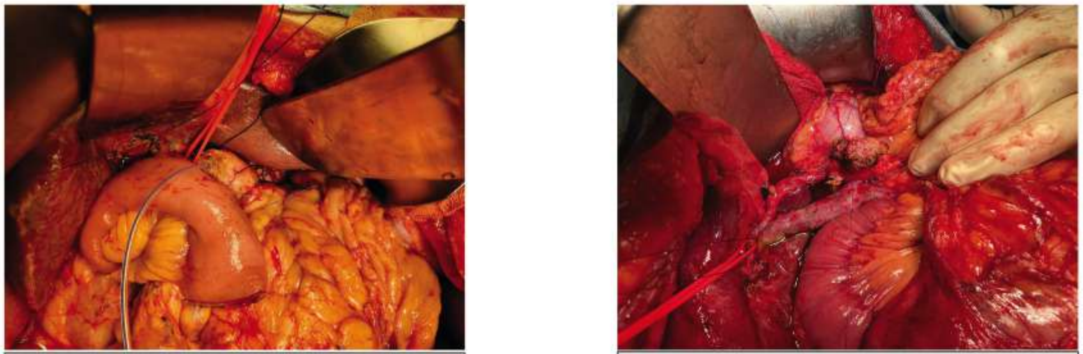
The usual order of reconstruction is pancreatico-enteric anastomosis, bilio-enteric anastomosis and gastro/duodenojejunostomy (Figure 11.8). Pancreatic anastomosis can be via pancreaticojejunostomy or pancreaticogastrostomy. Several techniques have been described to achieve either of these. Studies have not shown any consistent differences in outcomes between these variations. Anastomosis between the pancreatic duct and the jejunal mucosa requires meticulous technique using fine monofilament sutures in two layers and is generally preferred in a dilated pancreatic duct. In an undilated pancreatic duct, with a soft pancreas, some form of invagination/telescoping/dunking is


Step 1: Exploration and assessment of resectability
Step 2: Resection
Step 3: Reconstruction (pancreaticojejunostomy, hepaticojejunostomy, gastro/duodenojejunostomy)

11.8 Schematic diagram of PD. ⏎

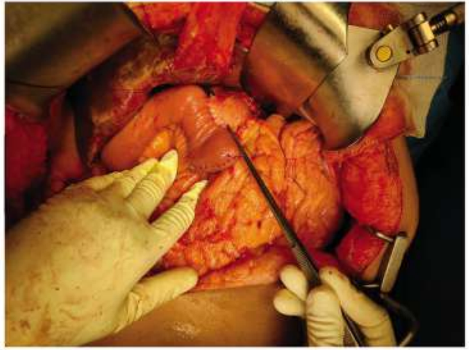

Step 1
Step 2
Step 3

11.9 Schematic diagram of pancreaticojejunostomy (duct-to-mucosa Cattell Warren type). ⏎



Jejunum brought near pancreatic stump

Pre-placed sutures in the pancreatic duct



Completed pancreaticojejunostomy

11.10 Intraoperative pictures of a pancreaticojejunostomy. ⏎

preferred (Figures 11.9 and 11.10). Bilio-enteric continuity is established with hepatico-jejunostomy using single-layer, interrupted, monofilament fine sutures. Stents across the biliary or pancreatic anastomosis are not the norm, but are used by some surgeons. Gastro/duodenojejunostomy is performed in an antecolic fashion with continuous double-layer or interrupted single-layer absorbable sutures. While routine use of drains has been questioned, most surgeons tend to use closed drainage systems with one or two drains to provide drainage to the pancreatic and biliary anastomoses. A nasogastric tube for upper gastrointestinal decompression is placed at surgery and may be removed early in the postoperative period. Enteral feeding tubes are useful to initiate early enteral feeding after surgery.

KEY CLINICAL POINTS

- Time spent in assessing preoperative imaging saves operative time, and this is more important for minimal-access surgery.
- Any aberrant vessels should be assessed on preoperative imaging and then again during surgery.
- The GDA is an important vessel in patients with coeliac artery stenosis and is the most common source of post-pancreatectomy haemorrhage.
- Pancreatic transection is the irreversible step of surgery.
- Pancreaticojejunostomy is the Achilles heel, as an uncontrolled leak can give rise to numerous complications.

POSTOPERATIVE COURSE

Common complications following PD include delayed gastric emptying (15%), pancreatic fistula (23%), post-pancreatectomy haemorrhage (7%), bile leak (4%) and 90-day mortality (3%). The overall complication rate is 55%, with severe complications (Clavien–Dindo grade III or more) in 25% as reported in a recent large review (Kokkinakis et al., 2022). Aside from routine postoperative care revolving around fluid and electrolyte management, surgeons must retain a high index of suspicion for anastomotic leak and septic complications of leakage. Pancreatico-enteric anastomosis is the Achilles heel of PD and, despite meticulous surgery, the leak rates remain high. Somatostatin analogues (e.g. octreotide) have been used prophylactically in the perioperative period to suppress pancreatic secretion in an effort to reduce the leak rates. The published evidence for somatostatin analogues is quite discordant, and most surgeons use this drug in high-risk pancreatic anastomosis (soft gland, undilated pancreatic duct, etc.). Enhanced recovery protocols have been successfully utilised after pancreatic surgery and have shown benefits in early recovery and good outcomes.

MINIMALLY INVASIVE PD

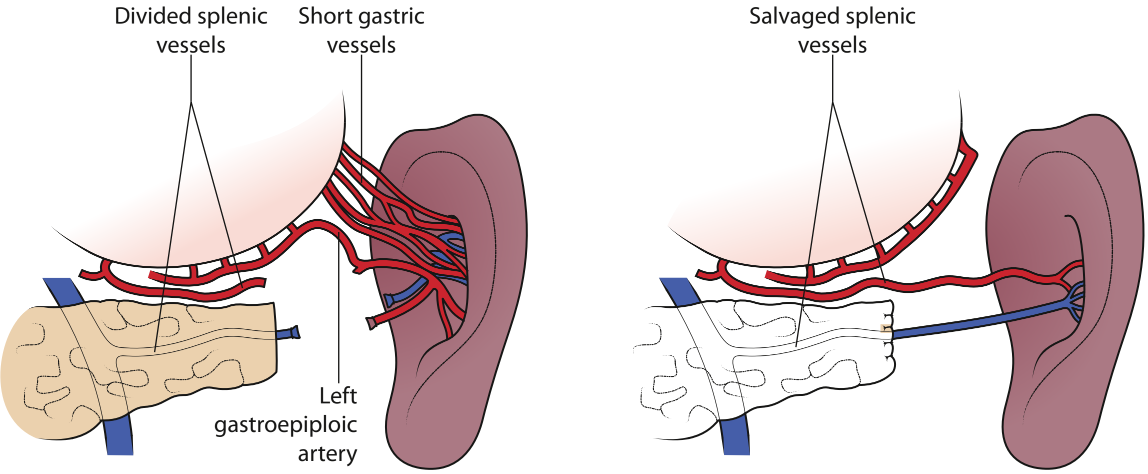
Gagner and Pomp (1994) introduced minimally invasive PD. The technique requires proficiency in both PD and minimal-access surgery. Several studies have reported the safety and feasibility of minimally invasive PD (both laparoscopic and robotic). Some studies have reported benefits in terms of reduced intraoperative blood loss, less delayed gastric emptying, shorter hospital stay and other benefits of minimal-access surgery. However, others have raised important questions about safety and long-term oncological benefits. The technical differences include patient position (reverse Trendelenburg), prolonged pneumo-peritoneum and the use of laparoscopic/robotic instrumentation. The steps of the surgery are broadly similar, although the field of dissection is viewed from a more caudo-cranial direction and the gallbladder is used to retract the liver cranially. The bile duct is often divided late in the procedure to avoid bile spillage and also to allow retraction of the specimen until the resection is completed. A Pfannenstiel incision is usually used to deliver the specimen in a specimen-retrieval bag. Robotic instrumentation may have an advantage over laparoscopic surgery during reconstruction and anastomosis. Some teams employ a hybrid approach, with laparoscopic surgery for resection and robotic surgery for reconstruction.

DISTAL PANCREATECTOMY

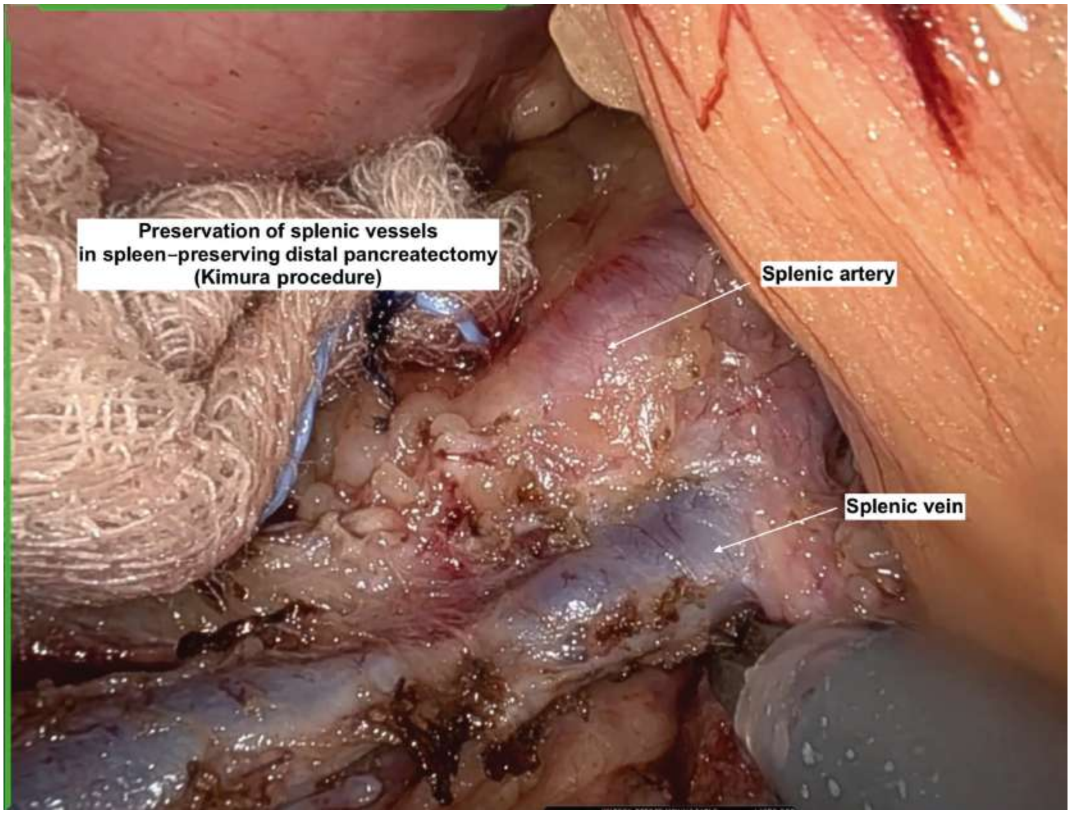
The indications for distal pancreatectomy are as follows:

- Tumours involving the body or the tail of the pancreas
- Trauma involving the body or the tail of the pancreas
- Uncommon for focal chronic pancreatitis, pancreatic fistula, pancreatic pseudocyst, etc.

En bloc splenectomy and lymphadenectomy is performed in combination with distal pancreatectomy for malignant neoplasms of the body or the tail of the pancreas. However, owing to the risk of post-splenectomy opportunistic infections, these patients should receive prophylactic immunisation, if time permits. In benign pathology situations, spleen-preserving distal pancreatectomy may be performed. There are two techniques to perform spleen-preserving distal pancreatectomy: the Warshaw technique and the Kimura technique (Figure 11.11). The Warshaw technique includes resection of the splenic artery and the splenic vein, along with the pancreas. These vessels are divided at the splenic hilum while preserving the short gastric vessels to maintain blood supply to the spleen. The Kimura technique involves preserving the entire length of the splenic artery and vein (Figure 11.12). Of the two techniques, splenic perfusion is best maintained by the Kimura technique, but operating time tends to be longer. Radical antegrade pancreaticosplenectomy (RAMPS) was proposed to improve margin negative resection and increased lymph node yield in malignant tumours of the distal



11.11 Schematic diagram demonstrating the difference between the Warshaw procedure and the Kimura procedure. ⏎


Preservation of splenic vessels
in spleen–preserving distal pancreatectomy
(Kimura procedure)
Splenic artery
Splenic vein

11.12 Minimal-access (robotic) spleen-preserving distal pancreatectomy (Kimura procedure). ⏎

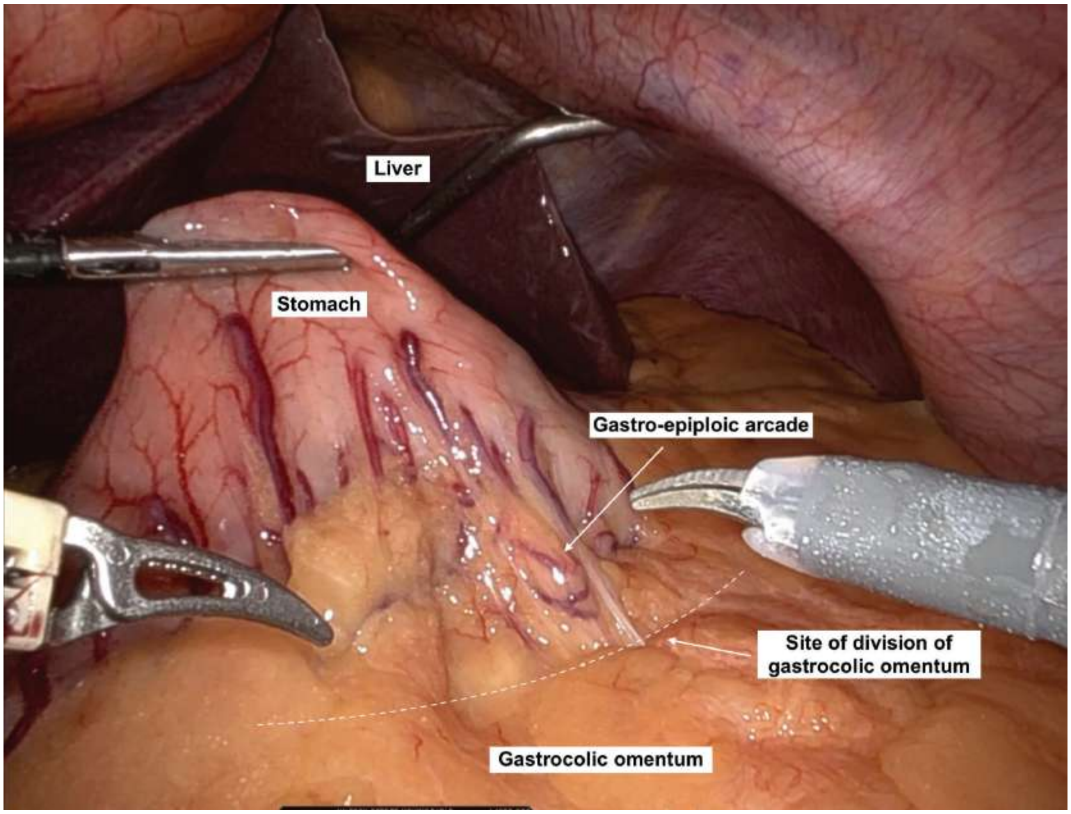
pancreas. In tumours not involving the posterior pancreatic capsule, anterior RAMPS is performed without including the left adrenal gland and Gerota's fascia. In those involving the capsule, a posterior RAMPS is required, which includes resection of the left adrenal gland and Gerota's fascia.

OPERATIVE PROCEDURE FOR DISTAL PANCREATICOSPLENECTOMY

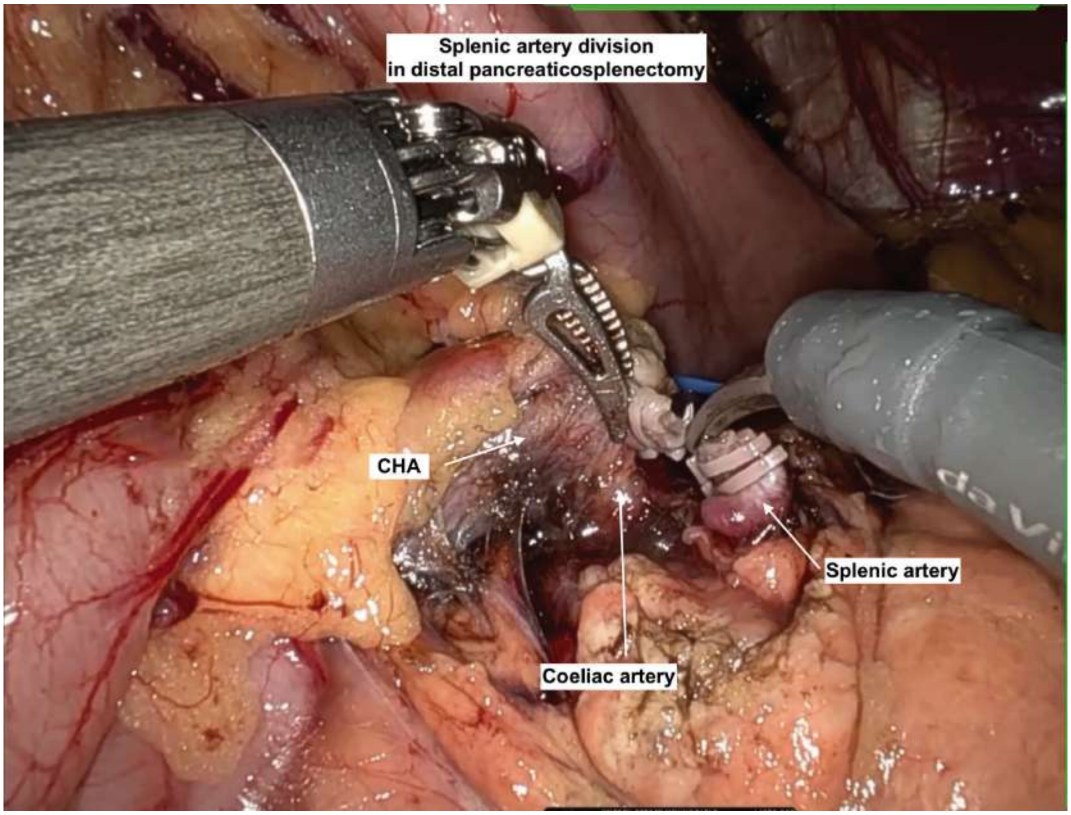
An upper midline incision, or a left subcostal incision with extension onto the right side, may provide adequate exposure. Appropriate costal margin retractors are employed to gain access to the abdomen and assessment of resectability. The lesser sac is entered by dividing the gastrocolic omental vessels from left to right, being mindful of the omental vascularity (Figure 11.13).

The short gastric vessels may be preserved only in a classical Warshaw spleen-preserving distal pancreatectomy. Cranial retraction of the stomach, and adhesiolysis in the lesser sac, exposes the pancreas in the retroperitoneum. Caudal traction on the transverse mesocolon exposes the inferior border and neck of the pancreas, and gentle caudal traction on the pancreas enables identification and taping of the splenic artery and CHA at the superior border of the pancreas. In the conventional distal pancreaticosplenectomy, the dissection moves laterally to mobilise the splenic flexure of the colon and division of the lateral splenic ligaments (splenorenal, splenocolic and splenophrenic) to mobilise the spleen medially off the retroperitoneum. The spleen, along with the distal pancreas and the splenic vessels, is mobilised off the retroperitoneum. The origin of the splenic artery is exposed and divided between ligatures (Figure 11.14).

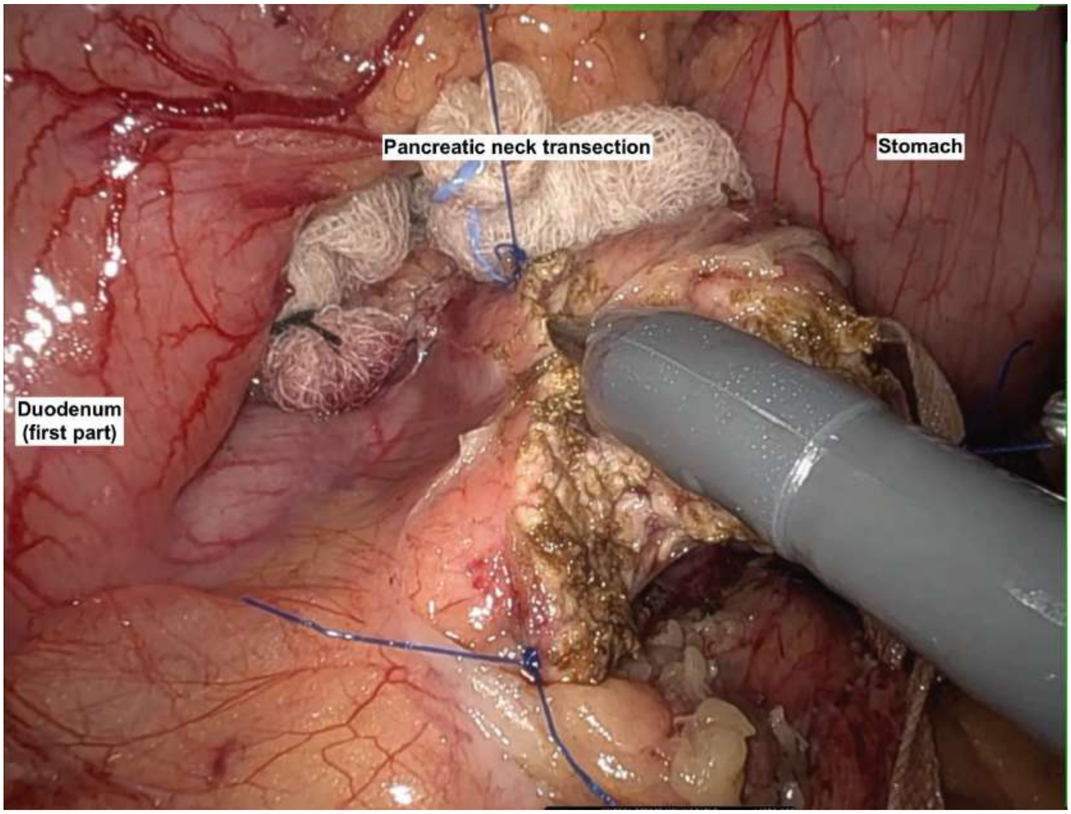
Alternatively, the splenic artery is divided earlier at the superior border of the pancreas at the designated point of transection before mobilisation. The splenic vein can then be controlled and divided behind the pancreas. Pancreatic division is the last step before specimen removal (Figure 11.15). In the RAMPS procedure, division of the pancreas at the neck is the first step, followed by division of the splenic vein at the splenic vein/SMV junction. The plane of dissection is then deepened to the left of the aorta to expose and divide the splenic artery, and all lympho-vascular tissue in the retroperitoneum is removed *en bloc* with the distal pancreas. The posterior plane of dissection then moves from right to left depending on the plan of anterior versus posterior RAMPS (as defined earlier). Pancreatic transection can be performed with scissors, an energy device or a stapler (Figure 11.16).


Liver
Stomach
Gastro-epiploic arcade
Site of division of gastrocolic omentum
Gastrocolic omentum

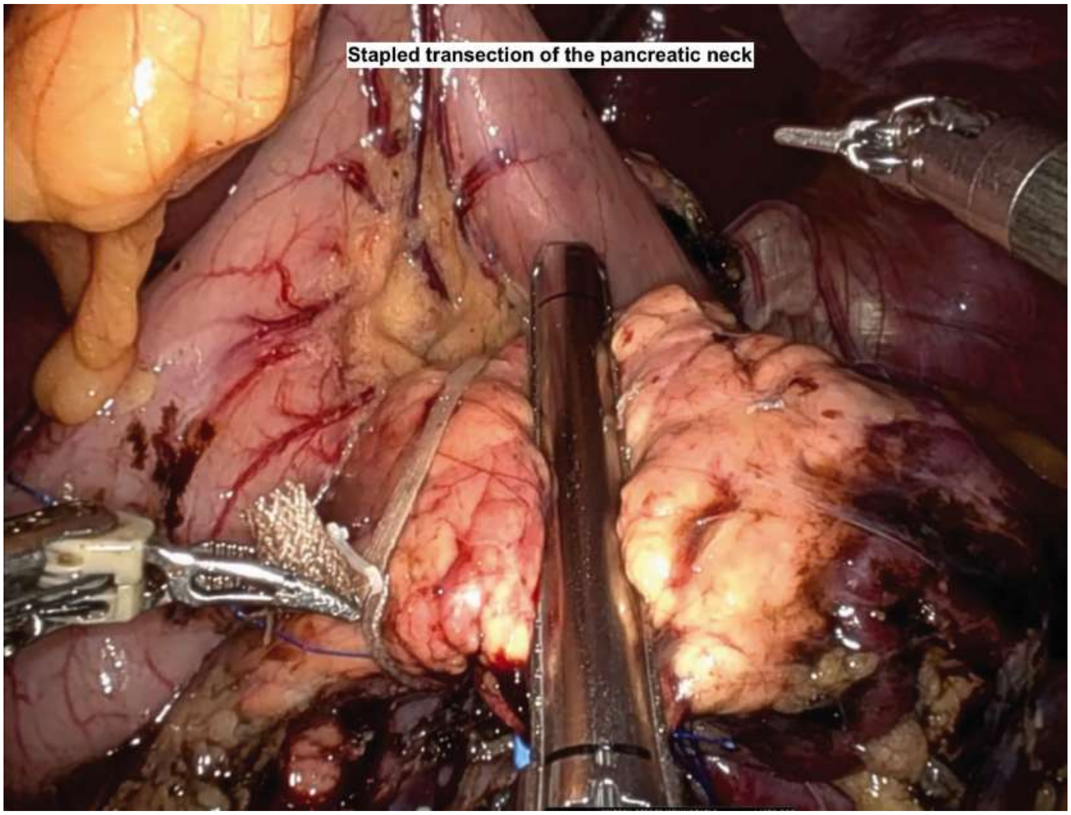
11.13 Operative picture of the opening of the gastrocolic omentum (robotic distal pancreatectomy). ⏎


Splenic artery division in distal pancreaticosplenectomy
CHA
Splenic artery
Coeliac artery

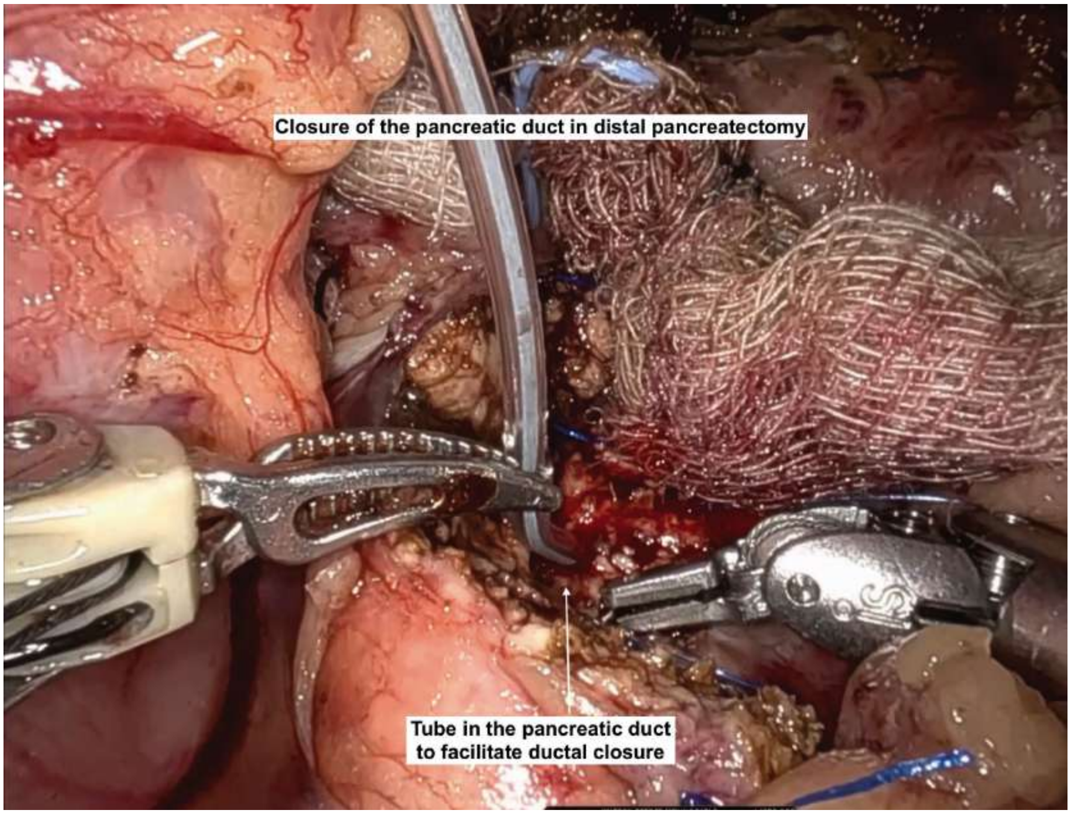
11.14 Splenic artery division in the case of distal pancreaticosplenectomy. ⏎


Pancreatic neck transection
Stomach
Duodenum (first part)

11.15 Pancreatic neck division in distal pancreatectomy (monopolar scissors in robotic distal pancreaticosplenectomy). ⏎


Stapled transection of the pancreatic neck

11.16 Stapled pancreatic neck division in minimally invasive distal pancreatectomy (robotic). ⏎


Closure of the pancreatic duct in distal pancreatectomy
Tube in the pancreatic duct to facilitate ductal closure

11.17 Pancreatic duct closure (robotic distal pancreaticosplenectomy). ⏎

Separate identification and closure of the pancreatic duct using fine monofilament sutures is advisable if a stapler is not used (Figure 11.17). Then the pancreatic stump is oversewn in 'fish-mouth' fashion with monofilament sutures (Figure 11.18).

Pancreatic stump leak and a pancreatic fistula occurs in 15–20% of patients, and no technique of pancreatic stump control has been shown to be consistently superior to the other. Hence, although questioned by many, effective drainage of the area is advisable after the surgery.

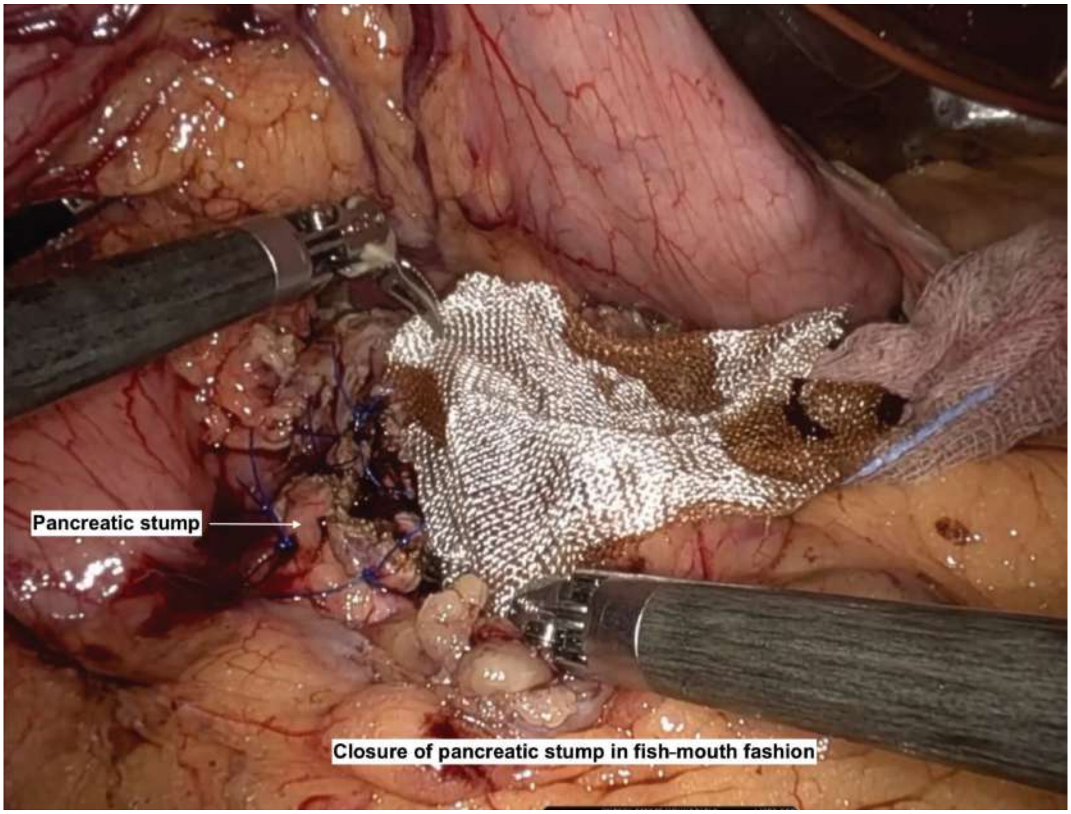
KEY CLINICAL POINTS

- Informed consent for splenectomy should be taken from the patient, even though it may not be required.
- Splenic preservation may be time consuming.
- Stapled pancreatic transection is favoured in cases of thin and soft pancreas.
- Minimal-access surgery provides short-term benefits to the patient.

Minimally invasive surgery (laparoscopic or robotic) may also be utilised for distal pancreatectomy, with good outcomes. The steps of the surgery remain broadly similar. Recently, minimally invasive distal pancreatectomy for adenocarcinoma has been shown to have non-inferior results to open surgery; however, concerns remain with regard to its broad applicability and long-term outcomes.

SURGERY FOR ACUTE PANCREATITIS

Acute pancreatitis can be a life-threatening acute illness and is associated with significant morbidity and mortality. Successful management relies on multidisciplinary, dynamic management of organ-specific support, management of infected necrotic material, and enteral or parenteral nutrition. Alcohol intake and cholelithiasis are the two most frequent causes of acute pancreatitis. Indications for surgery (emergency and elective) in acute pancreatitis include infected necrosis, perforation, vascular complications, pseudocysts, abdominal compartment syndrome, non-occlusive mesenteric ischaemia and surgery to prevent recurrent pancreatitis. For these indications, the surgeon usually has to consider the following surgical procedures: cholecystectomy, ERCP and various



11.18 Pancreatic stump closure (robotic distal pancreaticosplenectomy). ⏎

forms of necrosectomy with additional procedures, as appropriate.

ERCP IN GALLSTONE-INDUCED ACUTE PANCREATITIS

Emergency ERCP is indicated in patients with cholangitis and is best done within 24–72 hours of presentation. ERCP may also be indicated in patients with obstructive jaundice (i.e. due to an impacted CBD stone). MRCP may be performed to look for CBD stones prior to cholecystectomy. ERCP is indicated if bile duct stones are demonstrated, either before (preferably) or after the cholecystectomy. CBD stones demonstrated on intraoperative cholangiography may be treated at surgery or by postoperative ERCP.

CHOLECYSTECTOMY

Cholecystectomy is indicated in all gallstone-induced pancreatitis to prevent recurrence, except when the risk is prohibitive. Laparoscopic cholecystectomy is the standard of care. Early cholecystectomy is advisable, as soon as mild pancreatitis resolves, and delayed cholecystectomy is advisable in cases of severe acute pancreatitis, when the local and systemic complications have resolved. For patients with a prohibitively high risk for cholecystectomy, endoscopic sphincterotomy may reduce the risk of gallstone-induced pancreatitis.

SURGERY FOR PANCREATIC NECROSIS AND OTHER COMPLICATIONS

The ‘step-up’ approach to management of acute necrotising pancreatitis is the standard of care today. Septic complications are initially managed with percutaneous catheter drainage (PCD) (sometimes multiple). Around half of these patients may be successfully managed with this approach. Those who fail to respond to PCD management require consideration of necrosectomy. Current understanding has led to an approach where necrosectomy is carried out as late, and as minimally invasively, as possible. Most surgeons would aim to postpone necrosectomy until at least 4 weeks after the onset of pancreatitis when the necrosis is better localised. Infected necrosis is an indication for surgery, whereas, for sterile necrosis, surgery is not usually required. The diagnosis of infected necrosis may be confirmed by ultrasound-guided FNAC and culture, or may be diagnosed by serum inflammatory markers (e.g. procalcitonin) and supported by contrast-enhanced CT scan.

Open necrosectomy

Open necrosectomy still has a place in patients with extensive necrosis that is not amenable to minimally invasive treatment, especially when additional procedures such as diversion ileostomy/colostomy, surgery for perforation or control of haemorrhage are required. The general rule of necrosectomy is to gently remove easily separable, necrotic tissue using a finger or blunt instrument and saline jet spray. Copious irrigation and wide bore drainage tubes are required for postoperative large-volume irrigation to be continued. Decisions about packing and/or laparostomy need to be individualised to specific clinical scenarios. These patients need to be followed up clinically, and with repeat CT scan imaging, for planned re-exploration (re-look) if needed. These procedures are associated with 75% morbidity and up to 30% mortality.

Minimally invasive necrosectomy

This nomenclature encompasses a wide variety of procedures, including surgical necrosectomy (e.g. video-assisted retroperitoneal debridement [VARD] and laparoscopic necrosectomy), endoscopic necrosectomy (e.g. direct endoscopic necrosectomy), percutaneous necrosectomy (along the drain tract), etc. The choice of procedure is determined by the needs of the patient and the availability of local expertise. Minmally invasive necrosectomy decreases the overall complication rate, mortality and hospital stay when compared with open necrosectomy. However, minimal-access techniques are not universally applicable, or indeed available, in the management of all patients with pancreatic necrosis.

Video-assisted retroperitoneal debridement

This is a minimally invasive technique of removing retroperitoneal necrosis, and patient selection is key. It is best suited to patients with necrosis largely confined to the flanks (usually the left flank). In those with more widespread necrosis, VARD may be combined with other procedures, such as PCD. The patient is usually positioned supine with the flank elevated and widely exposed. As a guide to the necrotic cavity, a preoperative lumbar region PCD is placed posterior to the colon, in the retroperitoneal necrotic cavity. The cavity is reached by a limited flank incision around this PCD. The cavity is explored intially using deep-reaching conventional instruments and subsequently a laparoscopic camera and instruments, using the CT scan images as a guide. The necrosis is gently separated by blunt dissection using saline jet irrigation and an atraumatic suction tip. Firm strands crossing the cavity should be left intact, as these may be thrombosed vessels, and disruption may result in torrential haemorrhage. Wide-bore drains are placed in the cavity and the superficial muscle layer is closed (Figure 11.19). Postoperatively, immediate large-volume irrigation is instituted and the outflow is monitored for blood and enteric contents. Patients usually recover quickly, as the peritoneal cavity is not breached and there is limited tissue trauma. VARD is associated with lower morbidity (40%) and mortality (20%) as a part of the step-up approach.

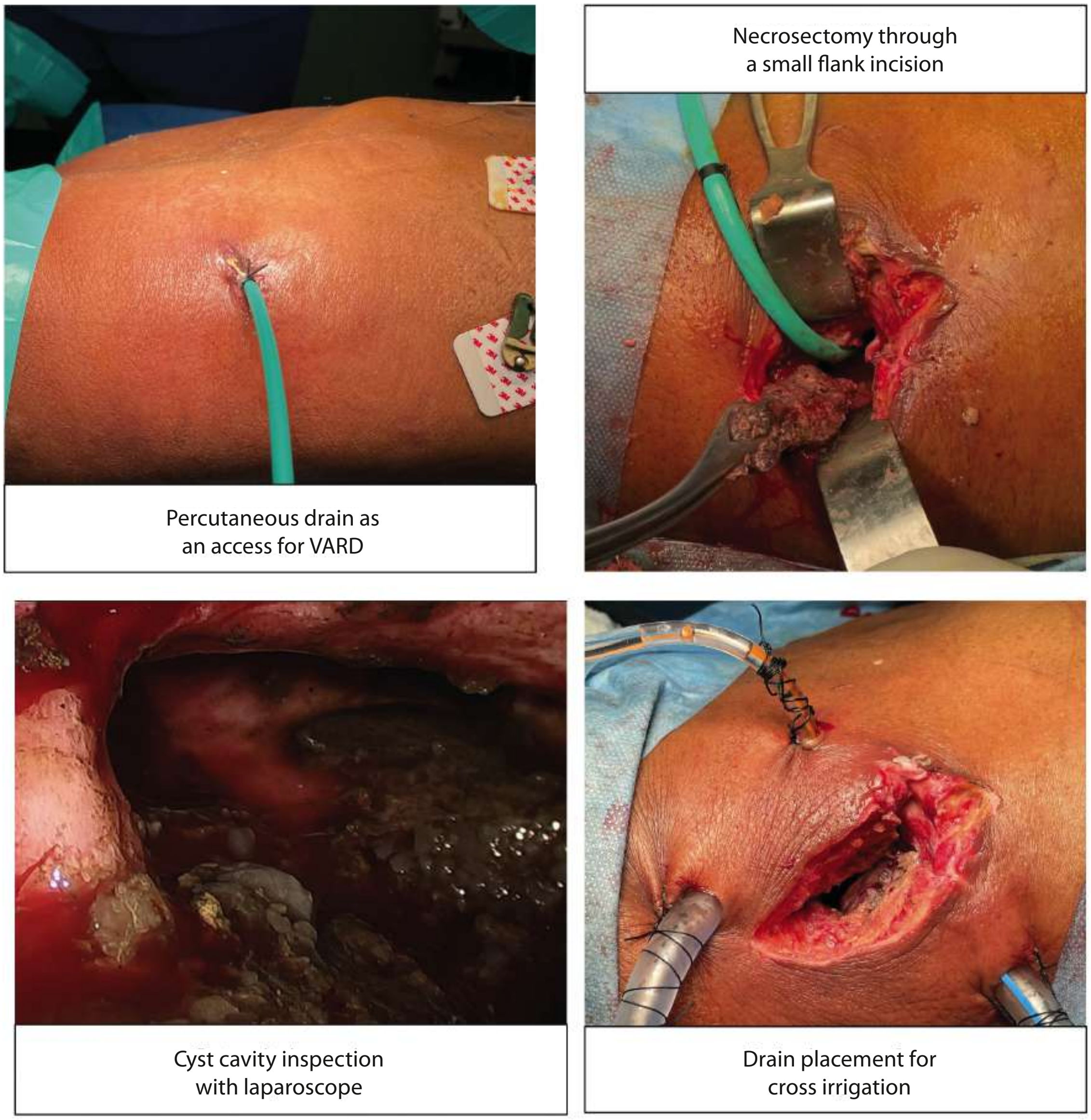
KEY CLINICAL POINTS

- Patient selection is important for necrosectomy.
- Necrosectomy removes easily detachable soft pancreatic necrotic tissue.
- Generous saline irrigation makes necrosectomy easier and safer.
- Cholecystectomy should be delayed in patients with severe biliary pancreatitis.

Additional procedures

Procedures such as diversion ileostomy/colostomy or feeding jejunostomy are mostly combined with necrosectomy but may be stand-alone procedures. Colonic perforation is mostly treated by faecal diversion, lavage and wide-bore tube drainage and is associated with high mortality. Rarely, repair, or resection, may be indicated. Haemorrhagic complications are predominantly managed by transcatheter embolisation. However, occasionally, these patients may need an urgent laparotomy for control of catastrophic haemorrhage.

A pseudocyst is defined as an encapsulated fluid collection with minimal, or no, necrosis. A pseudocyst is formed after 4 weeks of acute oedematous pancreatitis; however, it usually contains some amount of necrosis. The majority of pseudocysts resolve spontaneously, and asymptomatic pseudocysts do not require intervention. Pseudocysts may cause pressure symptoms on the surrounding organs (stomach and duodenum) or cause portal hypertension due to compression on the splenic vein, SMV or PV. Enzyme-rich fluid in the pseudocyst can weaken the vascular wall, causing pseudoaneurysm and subsequent bleeding. Hence, cysts in proximity to major vessels may need intervention. Internal drainage is preferred over external drainage, which includes a



Percutaneous drain as an access for VARD

Necrosectomy through a small flank incision

Cyst cavity inspection with laparoscope

Drain placement for cross irrigation

11.19 Steps of VARD. ⏎

cysto-gastrostomy or cysto-jejunostomy depending upon the location of the cyst. Endoscopic cysto-gastrostomy or cysto-duodenostomy may be feasible in some patients.

The management of gallstone pancreatitis is similar to pancreatitis of other aetiologies in many aspects. The controversial areas are whether, and when, to perform ERCP and cholecystectomy. In cases of pancreatitis with cholangitis, there is a role for early ERCP (<24 hours) and biliary drainage (European Society of Gastrointestinal Endoscopy guidelines). If ERCP is not feasible, then percutaneous transhepatic biliary drainage is preferred in an acute setting; however, there is no role for surgical CBD exploration. With regards to cholecystectomy, a randomised controlled trial (PONCHO trial) has reported a decrease in gallstone-related complications in same-admission cholecystectomy compared with interval cholecystectomy in the case of mild biliary pancreatitis (5% vs 17%, $p = 0.002$). In cases of moderate to severe biliary pancreatitis, early cholecystectomy is associated with increased morbidity (7.7% vs 3.7%, $p < 0.001$) and mortality (1.4% vs 0.1%, $p < 0.001$).

SURGERY FOR CHRONIC PANCREATITIS

Pain is the most common symptom of chronic pancreatitis leading to clinical presentation and consideration for intervention. In the majority of patients, pain can be managed without surgery. The treatment goals are the elimination of the causative agent (e.g. alcohol), prevention of acute pain episodes, long-lasting pain relief, prevention of disease progression, correction of metabolic consequences and improving the quality of life. These goals are pursued with the help of a multispecialty team, usually led by the gastroenterologist. Conservative treatment includes abstinence from smoking and alcohol, psychosocial support, pancreatic enzyme replacement therapy, antihyperglycaemic treatment, pain management and management of autoimmune pancreatitis. Endoscopic treatment is focused on pancreatic duct or bile duct stricture dilatation, pancreatic duct stenting and lithotripsy for pancreatic duct calculi, and management of complications such as a pseudocyst.

INDICATIONS FOR SURGERY

Pain in chronic pancreatitis may have several contributing factors including ductal hypertension due to obstruction, fibrosis, hypertrophied nerve fibres and neural hypersensitivity. Intractable pain is the most common indication for surgery. Other indications include suspicion of malignancy and management of complications (including biliary obstruction, duodenal obstruction, pseudocyst and intractable internal pancreatic fistula).

TIMING OF SURGICAL INTERVENTION

Neural hypersensitivity is the underlying pathophysiology of neuropathic pain and may be an important component of pain in chronic pancreatitis. Neural hypersensitivity correlates with a prolonged duration of uncontrolled pain. This has been the subject of recent studies and has led to the concept of early surgery to improve pain relief, prevent opioid dependence and provide cost-effective treatment. An important distinction needs to be made between surgery early in the course of the disease to, perhaps, change the natural history and preserve pancreatic function, on the one hand, and early surgery for intractable pain to achieve better pain relief, on the other. While recent evidence for the latter indication is quite robust (ESCAPE trial), the studies are less consistent for the former indication for surgery.

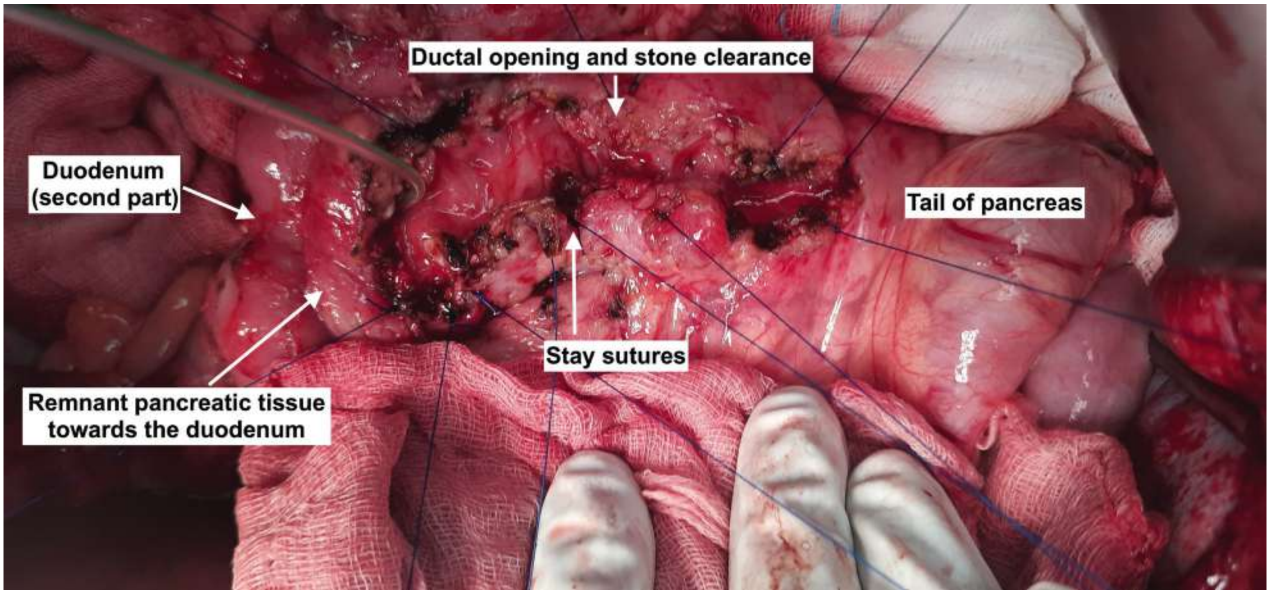
CHOICE OF SURGICAL PROCEDURE

Imaging findings that play a role in the selection of surgical procedures include the presence of an inflammatory head-of-pancreas mass, a dilated pancreatic duct, pancreatic duct strictures, extensive pancreatic calcification and suspicion of malignancy. The fitness of the patient to undergo the surgery required and the surgeon's experience are also important considerations. Surgical procedures can be classified into three categories: drainage procedures (Duval procedure, Puestow–Gillesby procedure or Partington–Rochelle procedure), resectional procedures (PD, distal pancreatectomy or total pancreatectomy with or without islet cell auto-transplantation) and hybrid procedures (Beger's duodenum-preserving pancreatic head resection, the Berne modification, Frey's procedure, the Hamburg modification or the Izbicki procedure). Studies have shown that resectional procedures provide better short-term and long-term pain relief, although these apply to specific patient populations. These procedures are largely carried out via open surgery, but some have been reported as being performed via minimally invasive surgery in recent years.

PARTINGTON–ROCHELLE LATERAL PANCREATICOJEJUNOSTOMY

The abdomen is explored through a midline or rooftop incision with the patient in the supine position. The lesser sac is accessed by dividing the gastrocolic omentum on the left side. Division of the gastrocolic omentum is extended to the right, and subsequent adhesiolysis in the lesser sac and cranial retraction of the stomach with caudal retraction of the transverse colon exposes the pancreas from the head to the tail. The Kocher manoeuvre is performed to facilitate control of the pancreatic head during surgery. The pancreatic duct may be located by palpation as a soft compressible area in an otherwise fibrotic pancreas. Intraoperative ultrasound can be helpful if there is difficulty in needle aspiration of the duct. After needle aspiration confirms the location of the duct, it is best opened at the neck/body junction and the opening extended with an energy device from the tail to the head up to within 1–2 cm of the ampulla. Aspirated pancreatic juice may be sent for culture. Pancreatic duct stones in the main duct, and side branches, are carefully removed as best as possible, along with the pancreatic stent, if present. Attention should be paid to clearance of the uncinate duct and any large side branches (Figure 11.20).

Thereafter, side-to-side pancreaticojejunostomy (Roux-en-Y) can be performed in a single layer with a monofilament continuous suture. The area is conventionally drained, but leaks are relatively uncommon. The postoperative course is usually quite unremarkable. This procedure has an overall morbidity rate of 20% and mortality ranges from 0% to 4.2%. However, there is a 40–50% recurrence rate of pain in the long term.


Ductal opening and stone clearance
Duodenum (second part)
Tail of pancreas
Stay sutures
Remnant pancreatic tissue towards the duodenum

11.20 Ductal opening and stone clearance in lateral pancreaticojejunostomy. ⏎

FREY'S PROCEDURE

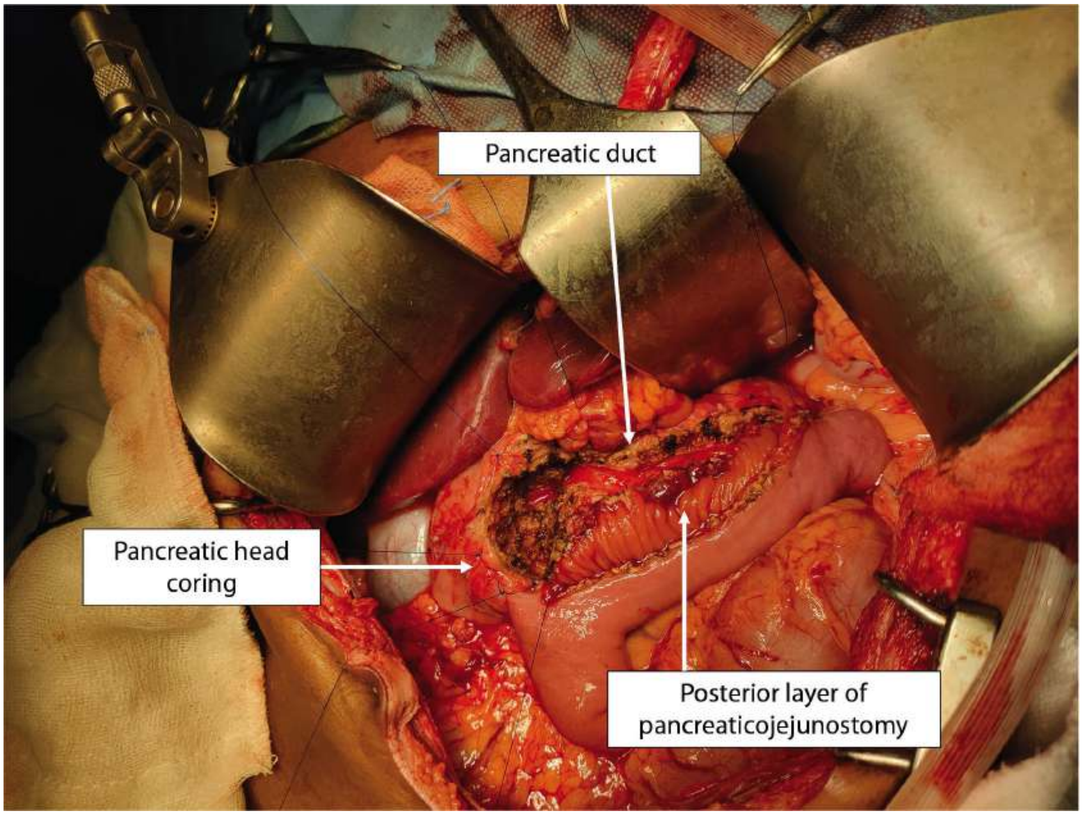
Indications for this procedure include a dilated pancreatic duct and an inflammatory head-of-pancreas mass, a stricture in the head or multiple pseudocysts in the head. The steps are generally similar to the Partington–Rochelle procedure, except in the pancreatic head. After opening the head of the pancreas duct, the tissues of the pancreatic head are removed ('cored') piece by piece, leaving a small rim of 5–10 mm of pancreatic tissue on the duodenal aspect and posteriorly up to the posterior wall of the pancreatic duct. When coring of the pancreatic head and uncinate process is completed, only a small part of the pancreatic duct is left and it should be probed to remove any residual calculi. Essential tips include control over the pancreatic head with a hand placed behind it during coring, meticulous haemostasis and adequate drainage of the uncinate process. Haemostasis should be carried out with judicious use of fine sutures, bipolar diathermy and an ultrasonic scalpel. Roux-en-Y pancreaticojejunostomy is performed as previously outlined (Figure 11.21).

In Frey's original description of the procedure, only a small rim of tissue is left behind in the pancreatic head; however, subsequently, it has been modified to limit the extent of posterior resection to the posterior wall of the pancreatic duct. It has a morbidity of 7.5–40% and a mortality of 0–2.4% and there is a 60–70% improvement in long-term pain relief.

BEGER'S PROCEDURE

Initial parts of the procedure are similar to the above up until the exposure of the pancreas and the Kocher manoeuvre. For the classical Beger's procedure, the retropancreatic tunnel is made over the SMV/PV as in PD and the neck is transected. The head of the pancreas is almost entirely removed, leaving behind 5 mm of tissue on the duodenum and the posterior capsule of the pancreas. Meticulous haemostasis is necessary, taking care to protect the duodenal vascularity. Ligation of the GDA may be necessary. Roux-en-Y pancreaticojejunostomy is performed as two separate anastomoses, with the margins of the pancreatic head cavity and with the divided neck of the pancreas. A distal bile duct stricture or inadvertently opened bile duct may be drained into the head cavity. The Berne modification of Beger's procedure differs in that the neck of the pancreas is not divided, as the retropancreatic tunnel can be quite difficult in chronic pancreatitis. Therefore, only a single anastomosis is required as the pancreaticojejunostomy. The other details are similar to the above operations. It has a morbidity of 15–54% and a mortality of 0–2%. In 80–90% of patients, there is improvement in pain scores; however, there is a risk of new-onset diabetes and exocrine insufficiency in 29% and 34% of patients, respectively.

Other resectional procedures that can be indicated in specific situations are distal pancreatectomy, PD and total pancreatectomy. Total pancreatectomy is indicated in the case of failed surgical procedures, patients who already have endocrine and exocrine insufficiency, diffuse chronic pancreatitis with multiple calculi in small ducts, diffuse disease in the pancreas without changes in the pancreatic duct, and failed conservative management. This procedure has a high morbidity (up to 40%) and mortality (5–10%). Total pancreatectomy can be combined with islet cell



11.21 Frey's procedure. ⏎

auto-transplantation in cases of small duct disease, in hereditary pancreatitis and in paediatric patients to preserve the endocrine function.

KEY CLINICAL POINTS

- Lateral pancreaticojejunostomy is reserved for patients with a dilated duct and no inflammatory head mass.
- Partial excision of the head ('head coring') is added to Frey's procedure if there is also an inflammatory head mass.
- Beger's procedure (or its modifications) is particularly useful in the case of an inflammatory head mass without a dilated pancreatic duct.
- PD is reserved for cases with suspicious malignancy in the pancreatic head mass.
- Intractable pain with an undilated duct and no head mass is a particularly vexing problem, usually treated by medical treatment. In the case of failure of medical therapy, the Izbicki procedure may be employed, with the understanding that pain relief is not as good as the above clinical scenarios.

COMPLICATIONS OF CHRONIC PANCREATITIS

Biliary obstruction

Biliary obstruction in chronic pancreatitis may be due to compression from a large pseudocyst or an inflammatory head mass, or may be due to a fibrotic stricture secondary to recurrent inflammation or, rarely, due to malignant change. Biliary obstruction due to compression can be addressed by treating the cause of compression (i.e. drainage of a pseudocyst or surgery for a head mass). Fibrotic biliary strictures take time to evolve from inflammation to mature fibrotic strictures. In this process, the serum liver function tests may show a transient intermittent rise in the alkaline phosphatase. However, persistently raised liver enzymes, obstructive jaundice, cholangitis and imaging evidence of biliary stricture are indications for intervention. Recently, endoscopic treatment of these strictures, with multiple stents, has become popular. However, surgery still appears to offer a better single-intervention and long-term solution to the problem. Surgical options include choledochoduodenostomy or Roux-en-Y choledochojejunostomy. Cholecystectomy forms part of the procedure owing to the resulting loss of physiological control of gallbladder emptying postoperatively.

Portal hypertension

Portal hypertension in chronic pancreatitis occurs due to partial or total occlusion of the spleno-porto-mesenteric axis. Porto-mesenteric occlusion is not an indication for surgery unless there is bleeding from the oesophageal or gastric varices. Patients with extensive collaterals may require a staged procedure. Bleeding due to left-sided portal hypertension is treated with splenectomy.

Duodenal obstruction

In most patients, duodenal obstruction is transient and due to inflammatory oedema and resolves spontaneously. Persistent fibrous obstruction may require a surgical bypass. PD is indicated in cases of pancreatic head mass with gastric outlet obstruction, particularly if there is suspicion of malignancy.

Pseudocyst of pancreas

A pseudocyst is a localised collection of pancreatic enzyme-rich fluid originating adjacent to the pancreas, surrounded by a wall of granulation tissue/fibrosis without epithelial lining, which occurs due to disruption of pancreatic ducts in chronic or acute pancreatitis. Accordingly, the pseudocyst is labelled as a chronic or acute pseudocyst, respectively. In acute pancreatitis, it is associated with a variable amount of necrosis while chronic pseudocysts usually contain clear pancreatic juice.

Cystic neoplasms of the pancreas may be considered as a differential diagnosis in some clinical scenarios. Contrast-enhanced MRI, with MRCP, is the most accurate investigation to evaluate a pseudocyst. However, in clinical practice, a contrast-enhanced CT scan be supplemented by EUS, and cyst fluid analysis is often performed.

The treatment of pseudocysts needs to incorporate consideration of the following factors:

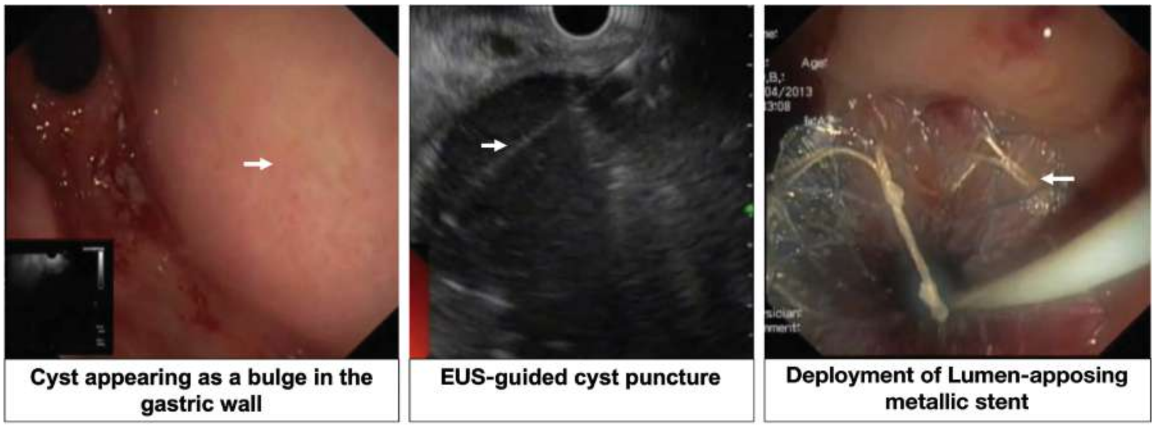
- *Location.* Cysts located posterior to the stomach, such that dependent drainage into the stomach can be achieved, are treated by internal drainage into the stomach.
- *Size.* Size alone is no longer an indication for drainage. An asymptomatic cyst can safely be followed up to resolution, especially if it is an acute pseudocyst.
- *Contents.* Acute pseudocysts associated with acute pancreatitis often contain some necrotic contents. This will need evacuation when the cyst is drained. Endoscopic drainage may not be adequate for a cyst containing a large amount of debris and hence surgical drainage may be indicated.
- *Pancreatic duct anatomy.* Any coexistent ductal strictures also need to be treated for resolution of the cyst. Trans-papillary stenting across the stricture will need to be performed to prevent refilling. However, in the absence of duct stricture, any duct communication can be addressed by a simple stent that crosses the ampulla.
- *Patient symptoms and pseudocyst type.* Acute pseudocysts (associated with acute pancreatitis) usually resolve spontaneously, and asymptomatic cysts may be managed by watchful waiting and followed up by imaging. Chronic pseudocysts (associated with chronic pancreatitis), on the other hand, do not resolve spontaneously due to ductal changes and usually need treatment, regardless of symptoms.

Endoscopic management Endoscopic drainage of the cyst can be either transmural or trans-papillary. Transmural drainage is indicated for cysts in proximity to the upper gastrointestinal tract. The procedure consists of an EUS evaluation of the cyst contents and a guided puncture through the bowel wall (usually the stomach). After aspiration, and confirmation, a pigtail plastic stent or a lumen-apposing metallic stent is deployed to drain the cyst contents. Trans-papillary drainage is chosen if there are duct strictures and leaks associated with the pseudocyst (Figure 11.22).

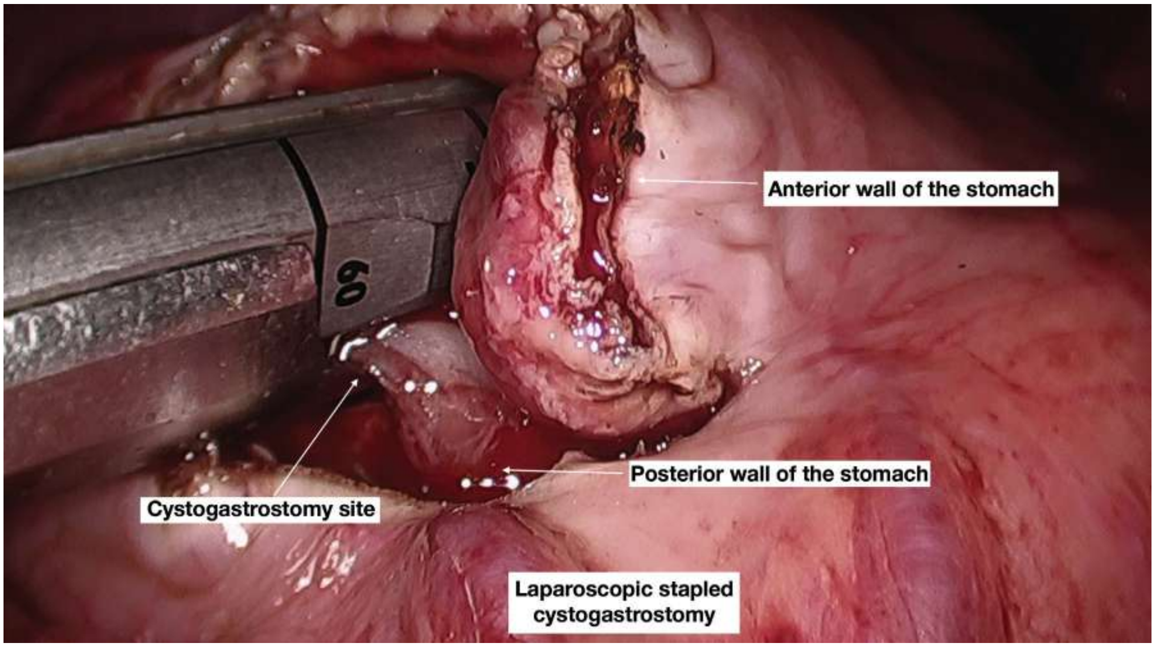
Surgical management The conventional procedure for pseudocysts has been internal drainage via an open cysto-gastrostomy (for cysts near the stomach) or cysto-jejunostomy (for cysts away from the stomach). The cyst is accessed through a midline laparotomy. During cysto-gastrostomy, the anterior wall of the stomach is opened between stay sutures, opposite to the bulge of the cyst behind the stomach. The cyst is confirmed by aspiration through the posterior wall of the stomach. The posterior wall of the stomach, and the adherent cyst wall, is opened between stay sutures and the cyst contents are evacuated. The cyst cavity is examined and irrigated. The posterior wall of the stomach and the cyst wall are sutured together with running locking (haemostatic) absorbable sutures. The anterior gastric incision is then closed in two layers. Drains are not indicated. Cysto-jejunostomy is done in a similar fashion with a Roux-en-Y loop of jejunum, except that the anastomosis is similar to that of a formal enteric anastomosis. These procedures can also be carried out successfully by minimally invasive surgery (laparoscopic or robotic) (Figure 11.23).

Pancreatic ascites

Pancreatic fistulae and ascites occur as a consequence of pancreatic duct disruption following trauma or acute or chronic pancreatitis and can also follow


Cyst appearing as a bulge in the gastric wall
EUS-guided cyst puncture
Deployment of Lumen-apposing metallic stent

11.22 Endoscopic cysto-gastrostomy. ⏎


Anterior wall of the stomach
60
Posterior wall of the stomach
Cystogastrostomy site
Laparoscopic stapled cystogastrostomy

11.23 Laparoscopic stapled cysto-gastrostomy. ⏎

pancreatic surgery or any operation where the pancreas was inadvertently damaged. The basis for successful management of both conditions is the attainment of effective pancreatic duct drainage using an approach similar to the management of pancreatic pseudocysts. For the majority, endoscopic pancreatic duct stenting results in the resolution of a pancreatic duct disruption, as long as a stricture does not exist between the site of disruption and the pancreatic stent. In cases where a stricture exists downstream to the site of duct disruption, surgical resection may be required. Effective pancreatic duct drainage may be supplemented using parenteral nutrition, a nil-by-mouth regimen and the prescription of octreotide to reduce pancreatic secretion.

SURGERY OF THE SPLEEN

ANATOMY OF THE SPLEEN

The spleen is located in the left upper quadrant of the abdomen under the costal margin and normally does not project beyond it. Some important anatomical relationships with surrounding organs are as follows: the diaphragm posteriorly and superiorly, the stomach medially, the left kidney and adrenal gland posteriorly, the phrenicocolic ligament and the splenic flexure of colon inferiorly, and the chest wall (9th–11th rib) laterally. The tail of the pancreas is related to the splenic hilum. The long axis of the spleen is in the direction of the 10th rib.

KEY CLINICAL POINTS

- Fracture of the 9th–11th ribs can be associated with underlying splenic injury.
- The inferior pole of the spleen grows anterior to the splenic flexure of colon as the spleen enlarges in splenomegaly.
- A left thoracostomy tube needs to be introduced above the upper pole of the spleen to avoid injury.

Peritoneum and ligaments of the spleen

The peritoneal layers enclose the spleen, except at the hilum, and two chief ligaments – namely the gastrosplenic and splenorenal ligaments – help to suspend it. Other minor ligaments include the splenophrenic ligament, splenocolic ligament, pancreaticosplenic ligament, phrenicocolic ligament, pancreaticocolic ligament and pre-splenic fold. The gastrosplenic ligament contains short gastric vessels, near the apex, and gastroepiploic vessels at its lower limit. The splenorenal or lienorenal ligament contains the tail of the pancreas and the splenic vessels.

KEY CLINICAL POINTS

- During surgery, the division of the short gastric vessels should be done with care using energy devices or ligatures, as these can be a source of significant haemorrhage, if not secured properly.

Vascular supply

The splenic artery is a branch of the coeliac trunk along with the CHA and the left gastric artery. It courses along the upper border of the pancreas, in a tortuous manner, to the hilum of the spleen. Other branches of the splenic artery include the short gastric artery, left gastroepiploic artery, posterior gastric artery, dorsal pancreatic artery, transverse pancreatic artery, great pancreatic artery and caudal pancreatic artery. The terminal branching may be magistral (division near the hilum) or distributive (division away from the hilum). The splenic vein originates from many smaller veins leaving the splenic hilum. The splenic vein receives tributaries from the pancreas and creates an indentation on the posterior surface of the pancreas. The splenic vein joins the SMV at the neck of the pancreas to form the PV. In 60% of cases, it receives tributaries from the inferior mesenteric vein before the formation of the PV.

KEY CLINICAL POINTS

- While ligating the proximal splenic artery, care must be taken to prevent inadvertent ligation of the CHA.
- Splenic arterial ligation with spleen preservation is feasible if the short gastric vessels and gastroepiploic arcade are intact, as in the Warshaw technique of spleen-preserving distal pancreatectomy.
- Ligation of the splenic artery should precede splenic vein ligation.
- Isolated ligation of the splenic vein should be avoided.
- The tortuosity of the splenic artery at the superior border of the pancreas facilitates its ligation.

Functions of the spleen

There are four major functions of the spleen: blood storage, haematopoiesis, filtration (culling, pitting) and immunological response. Hence, splenectomy leads to the absence of these functions and increases susceptibility to infection.

SPLENECTOMY

After the first description of splenectomy by Adrian Zacarelli in 1549, it was infrequently performed by surgeons due to prohibitively high morbidity and mortality. It was only after an improvement in surgical techniques and in the understanding of the surgical anatomy of the spleen that the morbidity and mortality decreased and, in modern practice, even minimal-access splenectomy is commonly performed. Splenectomy is indicated for trauma, where non-operative management fails, and for other non-traumatic causes. Non-traumatic indications can be segregated into haematological conditions (autoimmune thrombocytopenia, idiopathic thrombocytopenic purpura, hereditary spherocytosis, thalassaemia, etc.), neoplastic causes (Hodgkin's and non-Hodgkin's lymphoma, chronic myeloid leukaemia, chronic lymphoid leukaemia, haemangiomas, haemangiosarcomas, etc.) and other benign causes (pseudocyst, abscess, torsion, wandering spleen, etc.). Splenectomy may also be performed as part of other surgical procedures such as gastrectomy, shunt surgery or colectomy for advanced tumours.

Perioperative considerations

The spleen is an important part of the immune system protecting against infection. Post-splenectomy overwhelming sepsis is an important problem due to lowered resistance against infection with capsulated bacteria. Hence, when possible, patients should be immunised against *Pneumococcus*, *Meningococcus* and *Haemophilus influenzae* type B infection 1–2 weeks prior to splenectomy. In cases of emergency splenectomy, the immunisation may be done within 1–2 weeks of surgery after the patient has recovered fully. In addition, lifelong prophylactic antibiotics (oral penicillin or amoxycillin) have been recommended in all patients by some authorities, although the evidence for this is weak. Patients who had been receiving steroids preoperatively can have these tapered after surgery. Patients with myeloproliferative disorders are prone to develop SMV and PV thrombosis and, hence, should receive prophylactic, perioperative, low-molecular-weight heparin. In patients undergoing splenectomy for immune thrombocytopenic purpura, platelet transfusion may be given after ligation of the splenic artery.

Postoperative morbidity may include acute gastric dilatation (uncommon), basal atelectasis, haemorrhage, sepsis, etc. Pancreatic fistula can result from inadvertent injury to the pancreatic tail at the splenic hilum and can usually be managed conservatively with good drainage. Post-splenectomy thrombocytosis may pose a significant problem and may result in thrombotic complications and splenic vein/SMV/PV thrombosis, in particular. Platelet counts need to be monitored after surgery and, in patients with significant thrombocytosis, antiplatelet drugs should be commenced and specialist haematology advice should be taken.

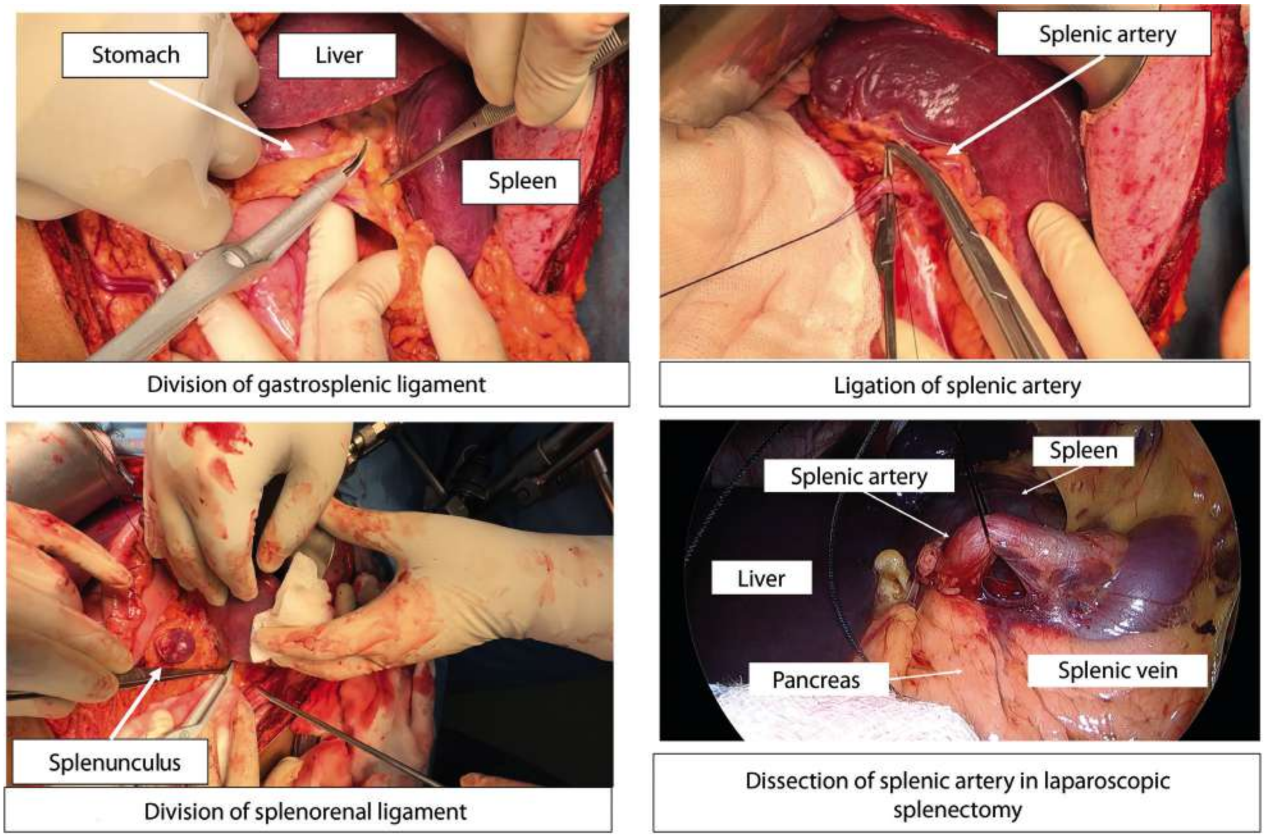
Operative procedure

An open splenectomy is usually performed through a left subcostal incision in the supine position with a slightly elevated left flank. In a large spleen, the options include an L-shaped, bilateral subcostal or thoracoabdominal incision. The spleen is exposed with appropriate retraction of the left costal margin, and a search for accessory spleens is undertaken. The lesser sac is opened, towards the left-hand side, and the division of the gastrocolic omentum is carried towards the left gastroepiploic vessels and the short gastric vessels. These vessels should be handled meticulously, as there is a risk of major haemorrhage and injury to the stomach or spleen. The splenic artery is ligated early at the superior border of the pancreas in large spleens, with care taken to prevent inadvertent ligation of the CHA. Early ligation of the splenic artery helps to shrink a large spleen and allows autotransfusion. Splenic mobilisation is carried out by dividing the surrounding splenocolic ligament and the splenorenal ligament. The splenic vein at the hilum should be dissected from the tail of the pancreas to avoid injury and pancreatic fistula. The splenic vein is ligated, and divided, at the end of the procedure and the specimen is delivered (Figure 11.24). Haemostasis is secured and a drain is placed at the splenic bed.

There are a few differences in the approach in patients with splenic trauma and those with a haemoperitoneum who have failed non-operative management. A midline laparotomy is used for quick access and for assessment of other injuries. A quick aspiration of the haemoperitoneum and perisplenic packing allows time for resuscitation. Meanwhile, exploration is performed to rule out other injuries. After the patient is stabilised, the packs are gently removed to assess the injury. If an expedient splenectomy is needed then the splenic hilum can be controlled with the surgeon's fingers or a large vascular clamp. Thereafter, the splenectomy can proceed accordingly. Often, it may not be possible to identify individual vessels, but all attempts should be made to safeguard the tail of the pancreas. Wide-bore drains are then placed in the splenic bed.

Spleen-preserving procedures

Spleen-preserving procedures are indicated for a mild splenic laceration or haematoma in a haemodynamically stable patient. Having ruled out other injuries, the best way to manage continuing slow haemorrhage is super-selective trans-arterial embolisation of the offending vessel. If haemorrhage continues, surgery may be required. At surgery, the options to preserve the spleen are splenorrhaphy or partial splenectomy. The spleen is mobilised and the whole organ is inspected. The site of bleeding can be controlled with pressure and application of haemostatic agents (oxidised cellulose, micronised collagen, thrombin or fibrin glue). Sometimes, repair with horizontal mattress sutures using pledgets is necessary before the application of haemostatic agents. At least 10–25% remnant spleen is required to maintain normal immunological function. Partial splenectomy removes the diseased segment of the spleen along with prevention of the long-term risk of overwhelming post-splenectomy infection or


Stomach
Liver
Spleen
Division of gastrosplenic ligament
Splenic artery
Ligation of splenic artery
Splenunculus
Division of splenorenal ligament
Splenic artery
Spleen
Liver
Pancreas
Splenic vein
Dissection of splenic artery in laparoscopic splenectomy

11.24 Intraoperative pictures during splenectomy. ⏎

thrombosis. The spleen consists of four or five segments and intersegmental planes, which are relatively avascular, and these form the basis of partial splenectomy. Some authors have suggested splenopexy to the stomach, or retroperitoneum, to prevent torsion.

Laparoscopic splenectomy

Laparoscopic splenectomy can be performed using an anterior or lateral approach. In the lateral approach, gravity aids in exposure. It is feasible and beneficial for small spleens, or for larger spleens when morcellation is acceptable. The patient is positioned in the right lateral position and the table is flexed at the level of the umbilicus with the table tilted to reverse Trendelenberg position. The surgeon stands on the right side of the patient and at least four ports are used. Open instruments need to be kept ready for intraoperative bleeding requiring conversion. The steps of the operation are largely similar to the open approach. Hand-assisted surgery is an option for manipulation and removal of very large spleens. The use of endovascular staplers to divide vascular ligaments and structures may expedite the steps. Even the hilum of the spleen can be divided with a vascular stapler, provided the pancreatic tail can be safeguarded. In benign cases, the specimen can be removed by morcellation or intact through a Pfannenstiel incision.

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Surgery of the liver

12

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ANATOMY

The liver is the largest of the abdominal viscera and constitutes nearly 2% of adult body weight. The surface anatomy of the liver bears little resemblance to the internal anatomy, which is of greater significance from a surgical standpoint. It is very important to understand the anatomy of the liver from two aspects, namely surface anatomy and functional anatomy.

SURFACE ANATOMY

The liver lies in close contact with the right dome of the diaphragm and extends partially under the left dome of the diaphragm. The liver can be described as having a diaphragmatic surface (divided into superior, anterior and right surfaces), which is separated from the inferior or the visceral surface by a narrow inferior border.[1]

Based on the surface appearance, the liver is divided into right, left, quadrate and caudate lobes by the various ligamentous attachments (peritoneal folds) of the liver that include the falciform, coronary, and right and left triangular ligaments. The falciform ligament divides the diaphragmatic surface of the liver into right and left lobes and extends inferiorly to the anterior abdominal wall. The quadrate lobe is bound by the gallbladder fossa to the right, the umbilical fissure to the left and the porta hepatis inferiorly. The caudate lobe is continuous with the right lobe and lies posterior to the porta hepatis and lesser omentum.[1]

The free border of the falciform ligament contains the ligamentum teres, which is the obliterated umbilical vein. Superiorly, the coronary ligament, which is the reflection of peritoneum from the diaphragm onto the superior and posterior surfaces of the liver, continues to the right and left as the right and left triangular ligaments. The triangular area lying between the two layers of the coronary ligament is called the ‘bare area’ of the liver because it is devoid of the visceral peritoneal covering and lies in direct contact with the diaphragm. It is important to expose this area during liver mobilisation for visualisation of the suprahepatic portion of the inferior vena cava (IVC).[1]

The porta hepatis is a transverse cleft on the inferior surface of the right lobe with the quadrate lobe lying anteriorly and the caudate lobe lying posteriorly. It transmits the portal vein, the hepatic artery, the hepatic ducts and the hepatic nervous plexus. The hepatic artery and the portal vein divide into left and right branches in the porta hepatis, just outside the liver substance. At the same level, the right and left hepatic ducts converge to form the common hepatic duct.

The lesser omentum is a peritoneal fold that is attached to the liver around the porta hepatis. From there, it stretches to the lesser curve of the stomach and the first part of the duodenum, with the hepatic artery, the portal vein and the bile ducts lying in its right free border. The common bile duct lies anteriorly and to the right, while the hepatic artery lies posterior, and to the left, of the bile duct. The portal vein lies posterior to the bile duct and hepatic artery. This free border forms the anterior boundary of the epiploic foramen into the lesser sac.

Glisson’s capsule

This is the fibrous capsule of the liver that becomes condensed as the perivascular fibrous capsules (Glissonian sheaths) around the branches of the portal triad structures as they enter the liver and subdivide into segmental branches. Thus, each bile duct, hepatic artery and portal vein is surrounded by a single fibrous sheath. This anatomical feature is utilised in the ‘Glissonian approach’ for sectoral and segmental liver resections.

Ligamentum venosum

The ligamentum venosum represents the obliterated venous connection between the left branch of the

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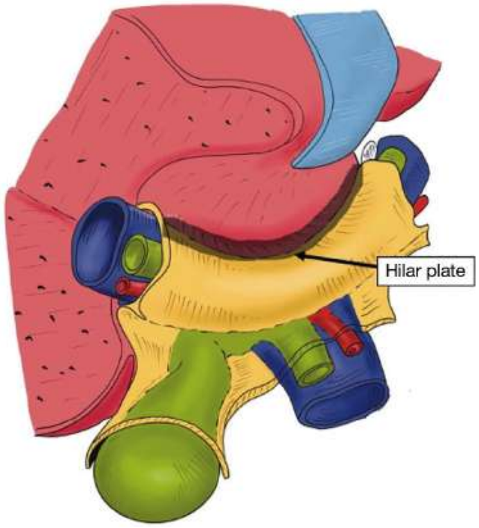
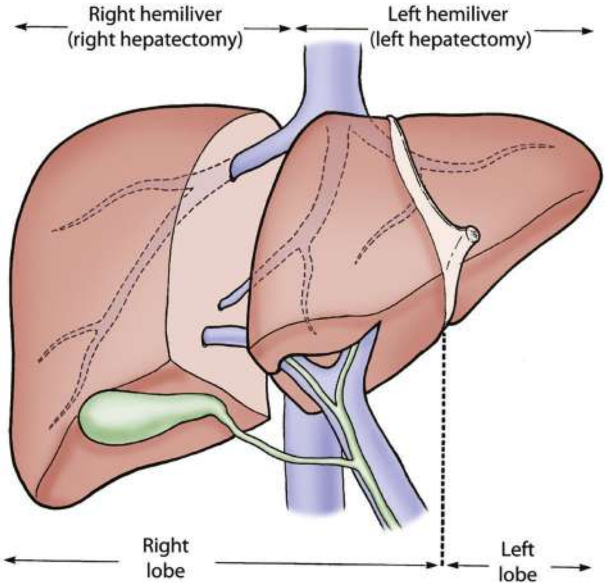


12.1 The hilar plate is the reflection of the Glissonian capsule between the porta hepatis and the base of segment IV of the liver. ⏎


Right hemiliver (right hepatectomy)
Left hemiliver (left hepatectomy)
Right lobe
Left lobe

12.2 Cantlie's line divides the liver into right and left hemilivers. ⏎

portal vein and the termination of the left hepatic vein (the ductus venosus). Division of the ligament close to its insertion into the left hepatic vein provides access to the left hepatic vein.

Hilar plate

This is the dense aggregation of vessels supporting connective tissue and liver parenchyma just superior to the porta hepatis (Figure 12.1). Lowering of the hilar plate is essential for optimum surgical access to the left hepatic duct.

FUNCTIONAL ANATOMY

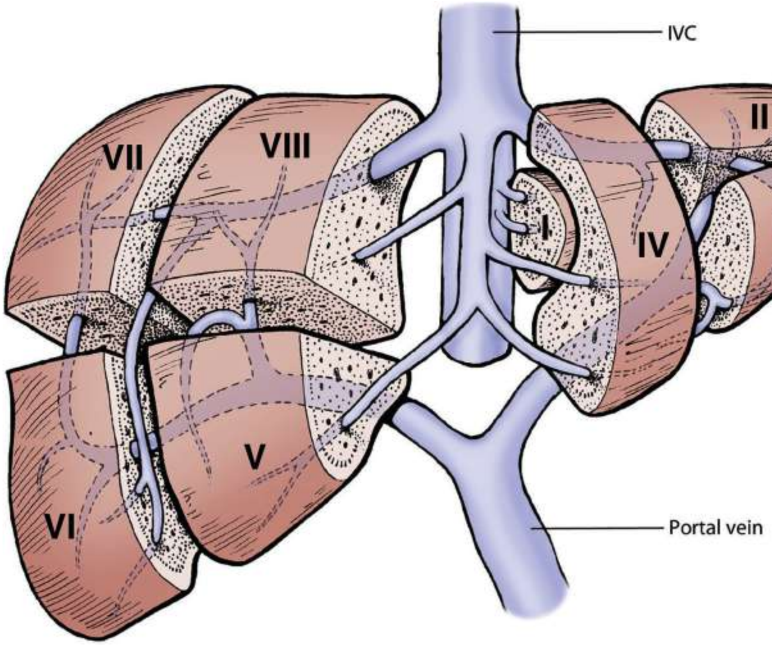
Our understanding of the functional anatomy of the liver is based on the seminal work of Couinaud (1957), Hjortsjö (1951) and Healey and Schroy (1953). According to Couinaud, the liver can be divided into two halves, or hemilivers, which are subdivided into four functional sectors and then further subdivided into eight functional segments (Figure 12.2). Between the four sectors there are three intersectoral planes called the portal fissures or scissurae. The three main intersectoral hepatic veins (right, middle and left) course through these portal scissurae. Each sector is subdivided into segments by the tertiary divisions of the Glissonian sheaths.[2]

The main portal fissure, also called Cantlie's line, extends from the midpoint of the gallbladder fossa to the midpoint of the IVC. The middle hepatic vein runs through the main portal fissure and separates the liver into right and left hemilivers. Segments V and VIII lie immediately to the right, and segment IV lies immediately to the left of the main portal fissure. Similarly, the left portal fissure that carries the left hepatic vein divides the left hemiliver into the left medial (segment IV) and left lateral sectors (segments II and III), while the right portal fissure that contains the right hepatic vein divides the right hemiliver into the right anterior (segments V and VIII) and right posterior sectors (segments VI and VII). The middle hepatic vein drains the right anterior and left medial sectors, the right hepatic vein drains the right posterior sector and part or all of the right anterior sector, and the left hepatic vein drains the left lateral sector and part of the left medial (segment IV) sector (Figure 12.3). All three hepatic veins converge superiorly and drain into the IVC. The caudate lobe drains directly into the vena cava via one or more separate veins.

PHYSIOLOGY

The liver performs numerous functions that can be broadly grouped into:

- Bilirubin metabolism
- Secretion of bile
- Metabolism of nutrients (glycogenesis, glycogenolysis, gluconeogenesis, fatty acid oxidation, cholesterol and lipoprotein synthesis, and protein turnover)
- Metabolic detoxification of toxins and drugs
- Immunological functions (filtering of portal blood, phagocytosis by Kupffer cells and the major site of antigen-presenting cells)



12.3 Segmental anatomy of the liver. ⏎

- Storage of vitamins (A, D, E, K and B12), iron and copper
- Endocrine functions (the activation of vitamin D, the conversion of T4 to T3 and hormone metabolism)

PREOPERATIVE INVESTIGATIONS

The preoperative assessment of a patient planned for liver surgery can be divided into three parts: (1) delineation of the characteristics of liver lesions such as size, number, location and relationship with the surrounding vascular and biliary structures, (2) assessment of the metabolic function of the liver and (3) calculation of the functional future liver remnant (FLR) if a large volume of liver parenchyma is expected to be removed.

IMAGING OF THE LIVER

Although a good-quality ultrasound scan is a useful initial screening tool, the mainstay of liver imaging remains cross-sectional imaging in the form of a contrast-enhanced computed tomography (CT) scan or magnetic resonance imaging (MRI). Contrast CT gives a good overview of the vascular anatomy of the liver. However, MRI is superior to CT in terms of picking up smaller lesions that are not visualised on CT, with MRI also providing superior morphological differentiation of the liver lesion and surrounding liver parenchyma. MRI carries the added advantage of providing a non-invasive cholangiogram in the form of a magnetic resonance cholangiopancreatography (MRCP). Multiple software packages are now available that allow three-dimensional reconstruction of the liver anatomy showing the precise location of liver masses and their relationship with surrounding vascular and biliary structures.[3]

Although changes suggestive of chronic liver disease can be picked up on cross-sectional imaging, ultrasound transient elastography is a useful tool for diagnosing advanced fibrosis and cirrhosis. This is an important consideration, as chronic liver disease remains asymptomatic and is not detected on routine liver function tests until a late stage in the disease process but has a bearing on the planning of major liver resections.

The role of a preoperative liver biopsy has largely been supplanted by cross-sectional imaging, particularly MRI, which can accurately differentiate benign from malignant lesions in the majority of cases. An invasive biopsy, which carries a potential risk of intraperitoneal bleeding and needle track seeding in patients with malignant tumours, is therefore not routinely required.

The routine liver function tests such as serum bilirubin, levels of liver enzymes, serum albumin and the international normalised ratio (INR) give a satisfactory assessment of metabolic function of the liver. Additional tests such a liver scintigraphy and indocyanine green clearance tests are recommended only when major liver resections are planned. Various scoring systems, such as the Child–Pugh score and the Model for End-stage Liver Disease (MELD) score, are useful adjuncts for functional assessment of the liver in patients with cirrhosis who are undergoing liver surgery.

GENERAL PRINCIPLES AND TECHNIQUES OF LIVER SURGERY

Since Langenbuch reported the first planned liver resection in 1888, liver surgery has evolved from a nearly impossible task fraught with major blood loss and high mortality to a stage where any part of the liver can be safely resected. The major milestones during this evolution of liver surgery have been our understanding of the physiology and segmental anatomy of the liver, the advent of advanced imaging techniques, the introduction of techniques and technology for controlling blood loss during surgery, an appreciation of the importance of volume and quality of the FLR, and advances in the field of anaesthesia for liver surgery. We have now reached a stage where complex resections can be performed, even in a cirrhotic liver, with minimal morbidity and mortality.

Advances in anaesthetic practice have ensured that nearly normal liver physiology can be maintained during the course of liver surgery. Maintaining a central venous pressure (CVP) of around 5 mmHg is just one such practice, although overzealous reduction of the CVP can have a detrimental effect on patient outcomes. The use of sevoflurane as an inhalational anaesthetic agent has been shown to reduce the incidence of ischaemia reperfusion injury after major liver resections.

GENERAL STEPS FOR A LIVER RESECTION

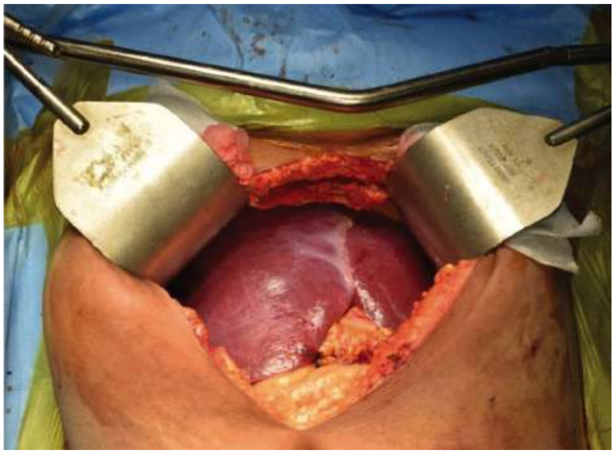
There are many variations in liver resections, but there are certain steps that are common to all. These steps can be broadly divided into:

- Access
- Exposure and mobilisation
- Inflow and outflow control
- Parenchymal transection

Access

The choice of abdominal incision depends on the patient habitus and the part of the liver to be resected. The commonly used incisions for access into the abdominal cavity during open liver surgery are:

- Upper midline incision
- Oblique right subcostal or transverse incision
- Reverse 'L' or Makuuchi incision
- Bilateral subcostal incision



12.4 Upper midline access and exposure of the liver using the Omni-Tract retractor system. The falciform ligament has been divided. ⏎

Most liver resections can be performed using an upper midline incision. Thoraco-abdominal incisions are no longer used and are of historical interest only. Due to an emphasis on the reduction of morbidity of access, minimally invasive (minimal-access) surgical techniques, both laparoscopic and robotic, are steadily replacing open liver surgery.

In open surgery, retraction of the costal margins is essential for adequate exposure of the liver. Fixed liver retractors, such as the Thompson or Omni-Tract retractor systems, provide excellent exposure of the liver during open liver surgery (Figure 12.4). Having exposed the liver, the next step is liver mobilisation.

Liver mobilisation

Division of the falciform ligament and ligation of the ligamentum teres is the first step during liver mobilisation. This is followed by division of the right or the left triangular ligaments, depending on the side of the liver to be resected. Early identification of the right hepatic vein prevents subsequent injury during the lateral and inferior mobilisation. Division of the left half of the lesser omentum is required for exposure of the caudate lobe. After full mobilisation, the liver is attached only by the hepatic veins to the vena cava and by the structures in the porta hepatis. It can be rotated out from its normal anatomical position into the surgical wound and packs placed behind it to maintain its position. These packs have the additional benefit of holding the liver in a position such that the anatomical plane between the two halves of the liver becomes vertical rather than oblique. A vertical plane is easier for the surgeon to identify and follow.

Liver dissection

Dissection of liver parenchyma is a skill that has to be learnt patiently. Various techniques and energy devices are used for this purpose. The Kelly clamp or clamp-crush technique is the oldest and simplest technique for parenchymal transection.[4] Although modifications of this technique are still used, it is largely used by various energy devices, the most popular being the Cavitron Ultrasonic Surgical Aspirator (CUSA). Other commonly used energy devices are a harmonic scalpel and water jet. Liver parenchyma is a highly vascular tissue and any incision into the liver parenchyma tends to bleed profusely. This bleeding can be minimised by following the intersectoral or intersegmental planes of the liver. These planes can be delineated by prior identification and ligation of the 'inflow' or the Glissonian sheath of that particular half, sector or segment of the liver. The commonly used techniques for vascular control are outlined below.

Pringle manoeuvre

The Pringle manoeuvre has stood the test of time since its first description in 1908.[5] It consists of placement of a soft occlusion (non-crushing) clamp, or occlusion tape, around the free edge of the lesser omentum, thus occluding the inflow to the liver from both the hepatic artery and the portal vein. Parenchymal dissection for a liver resection, or assessment of liver parenchymal injury in a patient, can then proceed with greatly reduced bleeding. If the occlusion does not arrest arterial inflow into the liver, an aberrant hepatic artery arising from the left gastric artery should be sought in the lesser omentum and an additional soft clamp placed across it. The 'safe' time for such occlusion is difficult to quantify. A variety of occlusion regimens have been reported. A 20-minute period of occlusion followed by removal of the clamp and reperfusion of the liver for about 5 minutes after each 20-minute period of occlusion can be safely recommended during transection of a normal liver. Total duration of intermittent clamping should not exceed 90 minutes. The length of occlusion time is reduced to 10 minutes if the liver is compromised or cirrhotic.

Early ligation of inflow

Early ligation of inflow has long been practised in right and left hepatectomies, whereby the hepatic artery and portal vein to the hemiliver to be excised are ligated in the porta hepatis before division of the parenchyma is commenced. The advantage of this approach is that the line of demarcation becomes apparent between well-perfused and ischaemic liver. This underlines the fact that there is little collateral flow between the two halves of the liver and that a surgical plane between the two halves should be relatively bloodless. The surgeon can then follow the plane accurately during dissection. The realisation that the perfusion of each liver segment is equally discrete should, in theory, allow a similar technique to be employed for segmentectomy, but it is often not possible to isolate the segmental inflow vessels for occlusion until some parenchymal dissection has been undertaken.

Lowering of the hilar plate

This is an essential initial step in dissection of the porta hepatis for securing inflow control during any major liver resection. In this procedure, the reflection of Glissonian sheath from the portal structures onto the base of segment IV of the liver is sharply divided. This is an avascular plane and, once the hilar plate is lowered, passing loops around the portal structures, especially the bile duct, can be performed safely.

Hepatic vein division

Major hepatic veins are wide and short structures. Simple ligation is contraindicated, as such ligatures tend to slip off. A transfixation suture is also not considered satisfactory, as it leads to bunching and distortion of the wall of the IVC. The only satisfactory method, other than a stapled closure, is a sutured closure. The vein is divided between clamps and oversewn with a fine monofilament Prolene® vascular suture. A monofilament suture, which slides through tissue without tearing, is essential, as all of the continuous suture must be in place before the clamp is removed and the suture tightened. If the clamp were to slip during this manoeuvre, haemorrhage from the vena cava could be torrential. Air embolism is also a potential danger, especially in a patient with a low CVP. A stay suture applied to both the superior and the inferior borders of any large vein, prior to division between clamps, is therefore recommended.

Hanging manoeuvre

This is a technique that facilitates the 'anterior approach' for resection of large tumours of the right lobe of the liver. It involves passing a rubber tape between the retrohepatic IVC and the liver using long artery forceps. Lifting of this rubber tape during liver transection allows liver partition without the need for prior mobilisation of the right lobe of the liver (see Figure 12.8). This technique helps in maintaining a nearly vertical plane of the liver and reduces blood loss during transection in deeper planes.[6]

Intraoperative ultrasound

An intraoperative ultrasound (IOUS) is a valuable tool for exact tumour localisation within the liver and for determining its relationship to adjacent vascular structures. This helps in increasing surgical precision, in parenchyma preservation and in reducing blood loss. All specialist hepatobiliary surgeons should be proficient at performing an IOUS. Both open and laparoscopic ultrasound probes are available for this purpose.

Energy devices and haemostatic agents

The energy devices that are commonly used during liver surgery include:

- *CUSA*. This is the optimum instrument for precise and delicate liver parenchymal dissection. It uses high-frequency ultrasound waves to dislodge the hepatocytes from the supporting connective tissue and Glissonian sheath.
- *Harmonic scalpel*. This instrument also uses the energy of high-frequency ultrasound waves to cut and coagulate tissues.
- *Vessel sealer (LigaSure)*. This uses a combination of pressure and bipolar energy to seal small blood vessels and tissues.
- *Water jet*. A high-pressure water jet is used in place of ultrasound waves to dislodge hepatocytes from connective tissue.
- *Electrocautery*. Electric energy is converted to heat, which in turn cuts and coagulates the tissues.
- *Argon beam coagulator*. This is a type of spray diathermy that is useful for controlling ooze from the cut surface of the liver.
- *Haemostatic agents*. These are absorbable, pharmacologically active materials that enhance clotting and are used as adjuncts for controlling oozing from raw surfaces. The underlying active material is oxidised regenerated cellulose in commonly available brands such as Surgicel Fibrillar. Fibrin glue is another surface haemostatic agent that recreates the last step of the coagulation cascade by converting fibrinogen to fibrin in the presence of thrombin.

LIVER RESECTION

Liver resections can be broadly divided into anatomical or non-anatomical. Anatomical resections are based on the segmental anatomy of the liver and involve inflow control via control of the Glissonian sheath supplying a particular segment, sector or half of the liver.

Non-anatomical resections entail removal of a small part of the liver along with the tumour and do not follow the segmental distribution of Glissonian pedicles. Such resections can be in the form of a small wedge resection of a peripherally located tumour or removal of a spherical chunk of liver parenchyma for a relatively superficially located tumour. Such resections are best performed using IOUS to guide the extent of resection and are often indicated for the removal of metastatic deposits from a primary colorectal cancer (CRC).

CLASSIFICATION OF ANATOMICAL RESECTIONS

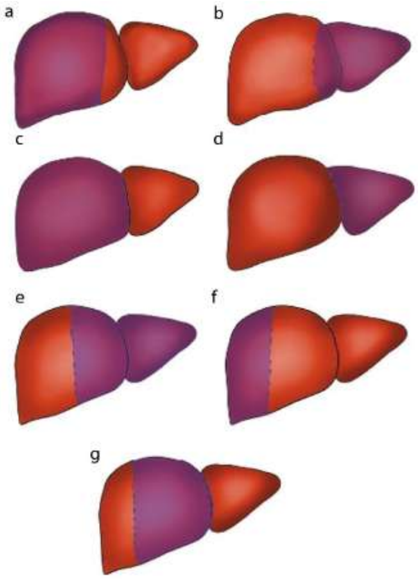
The terminology of anatomical resections is essentially based on the Brisbane classification (2000), which follows the segmental anatomy of the liver as described by Couinaud.[7] Subsequent modifications of this classification system have attempted to better define segmental and subsegmental resections.[8] Although each segment of the liver can be resected individually, the commonly performed liver resections in clinical practice are outlined in Table 12.1 and Figure 12.5.

Table 12.1 Commonly performed liver resections in clinical practice ⏎

Type of liver resection	Liver segments removed
Right hepatectomy	V–VIII
Left hepatectomy with or without the caudate lobe	II–IV (with or without segment I)
Extended right hepatectomy or right trisectionectomy	IV–VIII
Extended left hepatectomy or left trisectionectomy	I–V and VIII
Right posterior sectionectomy	VI and VII
Right anterior sectionectomy	V and VIII
Left lateral sectionectomy	II and III
Central hepatectomy	IV, V and VIII
Radical cholecystectomy	IVB and V

Right hepatectomy

This procedure involves the resection of segments V–VIII of the liver and can be performed via a midline or right subcostal incision. The plane of liver parenchymal transection follows Cantlie's line. The operation commences with division of the falciform, coronary and right triangular ligaments. The assistant rotates the liver to the left and the retrohepatic IVC

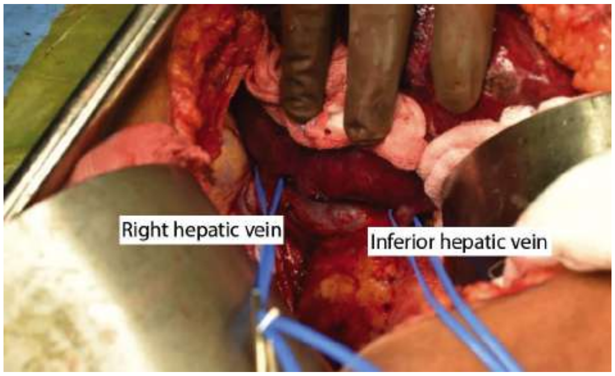


12.5 Commonly performed anatomical liver resections. (a) Right hepatectomy. (b) Left hepatectomy. (c) Extended right hepatectomy. (d) Left lateral sectionectomy. (e) Extended left hepatectomy. (f) Right posterior sectionectomy. (g) Central hepatectomy. ⏎

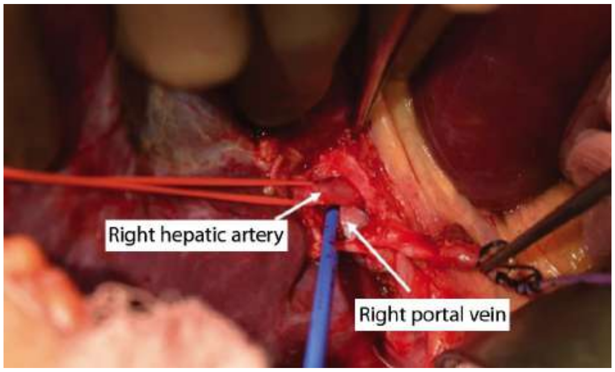
is exposed. Care must be taken to separate the right adrenal gland from the bare area of the liver. At this stage, the small hepatic veins draining directly into the IVC from the back of the right liver are divided between ligatures, but the main right hepatic vein should be left until the end of the operation to prevent venous engorgement. However, a band of fibrous tissue – the hepatocaval or Makuuchi ligament – should be divided in order to expose the right hepatic vein (Figure 12.6). This structure usually harbours a venous tributary, which must be secured.

The liver is then returned to a more neutral position, but with packs behind the right liver to lift it forwards into the wound. The packs rotate the right lobe of the liver so that the plane between the two halves becomes vertical. A cholecystectomy is then performed. The hilar plate is lowered, thus exposing the right hepatic duct, the right branch of the portal vein and the right hepatic artery (Figure 12.7).

The right hepatic artery is easily identified and then suture-ligated and divided. This exposes the right branch of the portal vein. A small caudate branch to the right portal vein should be divided prior to looping this vessel. The right portal vein should be divided after applying vascular clamps and the proximal vein should be sutured with 5/0 Prolene. Division of the right hepatic artery and the right portal vein produces a line of demarcation between the ischaemic right half and perfused left half of the liver (Figure 12.8).



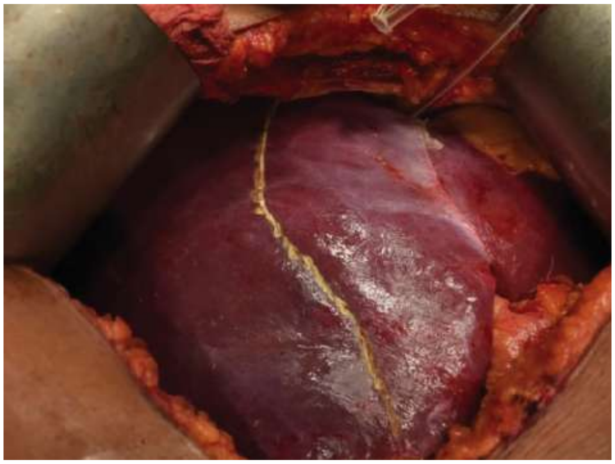
12.6 Exposure and looping of the right and inferior hepatic vein after division of the hepatocaval ligament. ⏎



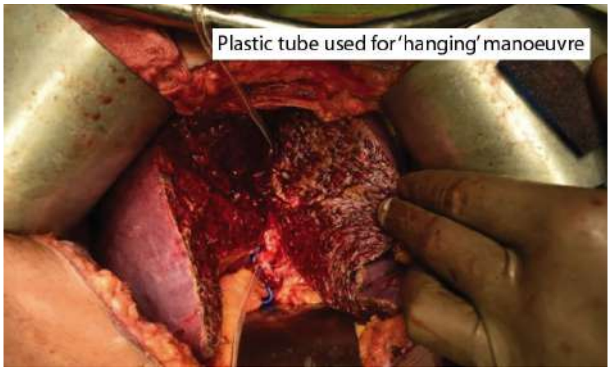
12.7 Dissection of the right Glissonian pedicle. Exposure and looping of the right hepatic artery and right branch of the portal vein. ⏎

While the right duct can be divided at this stage, it may be safer to take the duct later, during the parenchymal transection, to avoid inadvertent damage to the left duct. An alternative strategy is only to occlude the right hilar vessels with a soft clamp at the initial dissection in the porta hepatis. This will produce the same line of demarcation without the finality of a division, and all the structures of the portal triad can then be divided more distally at a later stage in the dissection. This may prove to be a safer option, especially if there are anatomical anomalies.[9]

Transection of the liver parenchyma is then commenced using any of the energy devices described above. This transection should be in the ischaemic half of the liver, approximately 5 mm from the line of demarcation (Figure 12.9). However, the line of transection will often have to encroach into the left hemiliver to ensure radical excision of more centrally based tumours. The middle hepatic vein lies in the plane of dissection and should be preserved, as it drains segment IV of the left liver. As one progresses with parenchymal transection, large hepatic veins draining segments V and VIII of the liver into



12.8 Marking of the ischaemic line. ⏎



12.9 Parenchymal transection along Cantlie's line for right hepatectomy. The hanging manoeuvre aids the transection. ⏎

the middle hepatic vein will be encountered. Each of these veins should be carefully divided between fine ligatures. In nearly 25% of cases, there is also a larger posteroinferior vein draining directly from segment VI into the vena cava, and this must also be divided.

The right hepatic vein may be divided and sutured by an extrahepatic approach, after the right hepatic artery and portal vein have been secured. Alternatively, the right hepatic vein may be dealt with from within the liver during the later stages of parenchymal transection.

After division of the portal structures to the right hemiliver, together with all parenchyma between the two hemilivers and division of all hepatic veins draining the right liver, the right hepatectomy has been completed. The cut surface must be checked for bile leaks from any unsecured biliary radicles. Typically, a white swab is used to identify any spot of golden-coloured bile. Any leak thus identified is then sutured with 6/0 Prolene sutures. Time should be taken to allow the anaesthetist to administer fluids to raise the arterial pressure and CVP to normal levels. Any bleeding site is sutured and haemostatic agents may be applied to the cut surface.

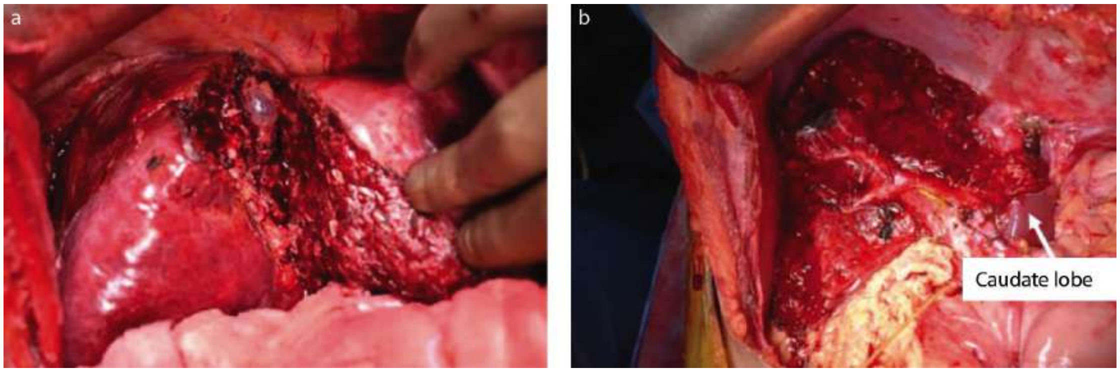
Left hepatectomy

In this procedure, segments I, II, III and IV are removed. As in right hepatectomy, the plane of parenchymal transection proceeds along Cantlie's line; however, the middle hepatic vein is preferably left with the remnant (right hemiliver) in order to preserve the venous drainage of the right anterior sector. Mobilisation of the left lobe requires division of the falciform, coronary and left triangular ligaments. Partial mobilisation of the right lobe by division of the right triangular ligament facilitates the procedure. The left half of the lesser omentum is divided, and it is important to check for the presence of an accessory or replaced left hepatic artery arising from the left gastric artery. If present, this artery is divided between ligatures. Division of the ligamentum venosum exposes the groove between the IVC and the junction of the left and middle hepatic veins. This plane is developed for extrahepatic looping of the left and middle hepatic veins. The caudate lobe is mobilised from the left side, gradually lifting it off the IVC and securing the short hepatic veins draining the caudate lobe during the process.

The gallbladder is removed if necessary. The principles of the portal dissection to ligate or control the structures in the left portal triad are similar to those required for the right portal triad in a right hepatectomy. As before, the left hepatic artery and the left portal vein are suture-ligated first, and the duct is divided during parenchymal transection. The dissection along the plane between the two halves of the liver is similar to that described for a right hepatectomy but, on this occasion, the dissection, which is made 5 mm inside the ischaemic half, is to the left of the middle hepatic vein. The vein is preserved, but tributaries to it from the left half of the liver are ligated and divided. The left hepatic vein must be secured with a running suture or stapled closure.

Left hepatectomy without the caudate (segment II/III/IV resection)

Segments II/III/IV segmentectomy is a modification of a left hepatectomy in which the caudate lobe (segment I) is preserved (Figure 12.10). This is a more common procedure, as most tumours do not encroach onto the caudate lobe. In the porta hepatis, the left hepatic artery and portal vein are ligated, but preferably distal to the branches that run posteriorly into the caudate lobe. This lobe receives arterial and portal inflow from both halves of the liver, and the biliary drainage is similarly split. The venous drainage is directly into the IVC. Part or all of the caudate



12.10 Left hepatectomy. (a) Transection plane for left hepatectomy. (b) Remnant right lobe and caudate lobe after removal of specimen. ⏎

lobe can therefore be retained in a left hepatectomy. During this procedure, the dissection of the caudate lobe from the IVC is not required and, during parenchymal transection, segments II, III and IV are separated from the caudate lobe by dissection along the ligamentum venosum. The left hepatic vein is secured just as in standard left hepatectomy.

Left lateral sectionectomy (segment II/III resection)

The falciform, coronary and left triangular ligaments and the left half of the lesser omentum are all divided to increase mobility, and the left liver is rotated forwards with packs placed behind it. The umbilical ligament is first followed deep into the umbilical fissure. This brings the dissection directly onto the left portal triad and its main biliary and vascular branches to the segments of the left liver. The segmental branches to segments II and III to be excised are ligated and divided. The branches of the portal triad that turn back to segment IV are preserved. The parenchymal transection plane is immediately on the left side of the falciform ligament and is a relatively easy plane to follow. Superiorly, the left hepatic vein is in the plane of the dissection. It is more superficial than is sometimes anticipated, and care must be taken not to damage the vein before it can be safely isolated, ligated and divided.

Extended right hepatectomy

In this resection, segments V, VI, VII and VIII of the right liver are excised along with segment IV from the left liver. The caudate lobe also needs to be resected if the procedure is for a hilar cholangiocarcinoma. An adequate volume of the remnant liver (segments II and III) should be ensured before proceeding with this procedure. Liver mobilisation is similar to that of right hepatectomy. Short hepatic veins draining into the IVC are secured and the right hepatic vein is looped just as in right hepatectomy. Cholecystectomy is performed and the dissection in the porta hepatis isolates the right branches of the portal triad in a manner similar to the dissection for a right hepatectomy. They are then usually ligated and divided at this stage rather than merely controlled. The Glissonian pedicle to the left hemiliver is not disturbed. The plane of parenchymal transection is on the *right* side of the falciform ligament and umbilical fissure. The vascular and biliary structures supplying or draining the segments to be retained should lie protected on the left of the falciform ligament during the initial dissection, but great care must still be exercised to avoid any damage. The branches turning back from the left portal triad to segment IV are individually ligated and divided. Once the transection reaches near the hepatic venous confluence, the middle hepatic vein will be encountered. This is a large vein and requires meticulous parenchymal dissection for exposure of adequate length. This vein is divided between vascular clamps and the distal (IVC) end is secured with a running suture. Once the parenchymal transection is complete and the right hepatic artery, portal vein and bile duct have been divided, the only structure left behind is the right hepatic vein, which is divided after applying a vascular clamp at its junction with the IVC.

Extended left hepatectomy

This resection involves the removal of segments V and VIII along with the left hemiliver. The caudate lobe is also removed when the resection is for a hilar cholangiocarcinoma (CCA). The operation commences with a dissection in the hilum, as for a left hepatectomy. The position of the ligatures on the structures of the left portal triad will depend on whether segment I is to be excised or preserved; a ligature can be placed more distally to preserve a vessel or duct to this segment.

The line of the parenchymal transection is along the anterior border of segments VI and VII. Since there are no reliable surface markings to identify this nearly horizontal plane between the anterior and posterior sectors of the right liver, IOUS is often used to delineate the right hepatic vein that runs in the right portal scissure. The transection line is marked on the liver surface about 5 mm to the left of the right hepatic vein. One can also adopt the 'Glissonian approach' for demarcating the transection plane between the anterior and posterior sectors of the right lobe. After lowering the hilar plate, the right Glissonian pedicle is looped. Following this, a plane is created between the right anterior and posterior Glissonian pedicles by blunt dissection. The anterior Glissonian pedicle is then looped and divided between clamps, resulting in an ischaemic area demarcating the right anterior from the right posterior sector. The parenchymal transection plane is along the left border of this ischaemic zone.

For ease of parenchymal transection, packs are placed behind the right lobe of the liver to shift the liver as far forwards as possible. As a consequence, the anatomical plane between segments V/VIII to be excised and segments VI/VII to be retained moves from horizontal to near vertical. It must be remembered that the position of the right hepatic vein is also shifted forwards, putting it at risk during dissection. The parenchymal transection plane progresses in a relatively bloodless plane along the left border of the right hepatic vein. Once the parenchymal transection is over, the specimen is retrieved after division of the left and middle hepatic veins between vascular clamps (Figure 12.11).

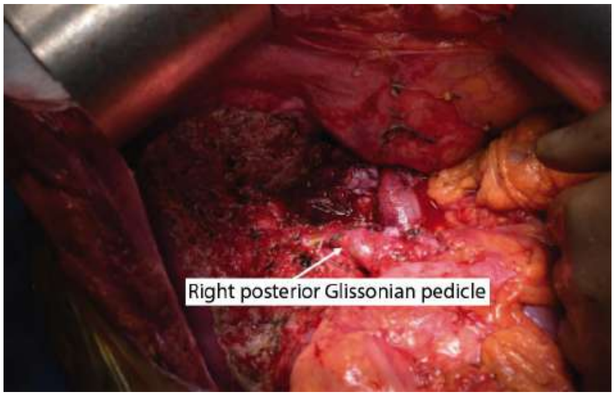
Right posterior sectionectomy (segment VI/VII resection)

These segments may be excised together or one segment may be excised on its own. Since there are no surface landmarks to delineate the transection plane between the right anterior and posterior sectors, either IOUS or the Glissonian pedicle approach is used to mark the transection plane along the left border or right hepatic vein (as described for extended left hepatectomy). In the Glissonian approach for right posterior sectionectomy, the right posterior Glissonian pedicle is looped and divided as part of inflow control and for marking the transection line. The right hepatic vein is usually removed with the specimen; however, it may be preserved if the tumour is located away from this vein. The technique of parenchymal transection is the same as for extended left hepatectomy.

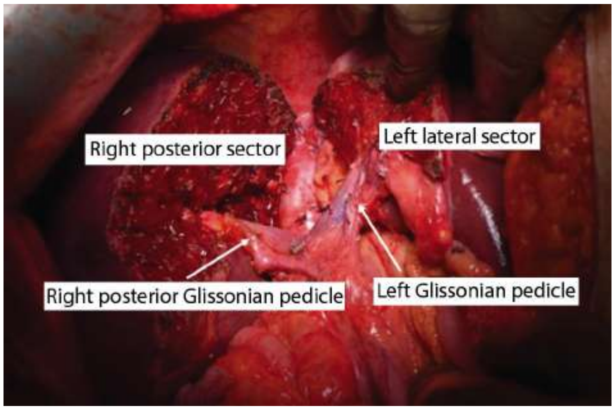
Central hepatectomy and liver resection for gallbladder cancer (segment IV/V/VIII resection)

In central hepatectomy, segments IV, V and VIII of the liver (with or without the caudate lobe) are removed, and this involves parenchymal transection along two planes. The left plane passes along the right border of the falciform ligament as in extended right hepatectomy, while the right plane lies between the right anterior and posterior sectors of the liver and is demarcated using IOUS or by the Glissonian pedicle approach as described above for extended left hepatectomy. The middle hepatic vein is divided within the liver parenchyma near its junction with the IVC (Figure 12.12).

A radical resection for cancer of the gallbladder may necessitate either a segment IVB/V segmentectomy or a IVB/V/VI segmentectomy. Resections in the central portion of the liver may be confounded by the proximity of the lesion to be excised to the structures of the porta hepatis and the IVC. An intact vascular inflow and outflow – as well as biliary drainage – to the remaining liver must be preserved, or reconstructed, and an understanding of the anatomy is essential in both the planning and the execution of these resections.



12.11 Right posterior sector remnant after an extended left hepatectomy. ⏎



12.12 Liver remnant after a central hepatectomy. ⏎

The dissection for these central segmentectomies follows the planes already described; however, further details of these resections are beyond the scope of this book and further reading on this subject is recommended.

MINIMALLY INVASIVE LIVER SURGERY

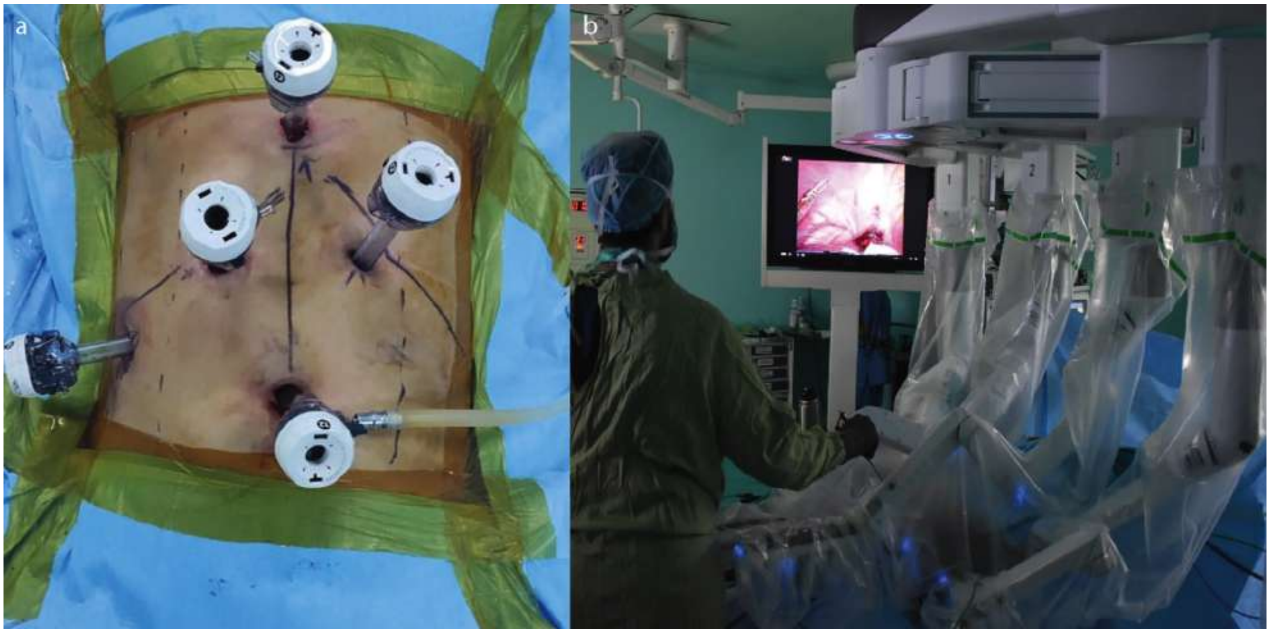
Minimally invasive surgical (MIS) approaches to liver resection have been increasingly adopted for liver resections for both benign and malignant liver pathology.[10] Minimally invasive liver surgery can be either laparoscopic or robot assisted (Figure 12.13). Although all of the major hepatic resections discussed above have been performed successfully using the MIS approach, the most favourable lesions are those that are less than 5 cm in diameter and located in the peripheral segments (segments II–VI). The 'split leg' position is preferred for most resections, except for right posterior segment resections. Results of randomised trials have not only established the safety of an MIS approach for liver resections but also shown that MIS resection is associated with less intraoperative blood loss, reduced postoperative pain, early ambulation and shorter hospital stay than open resections. Moreover, the oncological outcomes in terms of 5-year overall and disease-free survival are no different between the two groups.[11] Robotic-assisted liver resections may provide better access to tumours located in difficult-to-reach segments of the liver, such as segments VII, VIII and IVA. Another benefit to an MIS approach is the earlier initiation of adjuvant systemic chemotherapy.

PARENCHYMA-PRESERVING LIVER SURGERY

The principle of parenchyma-preserving liver resection for liver tumours is to maximise the FLR by removing the minimal amount of liver tissue required to achieve negative surgical margins. Parenchymal-preserving surgery reduces the physiological impact of surgery, thereby reducing complication rates and minimising the risk of postoperative liver failure. These benefits are more pronounced in patients with cirrhotic livers, thus allowing a greater number of patients to be eligible for surgical therapy for liver tumours.[12] Success of parenchymal-preserving surgery is dependent on advanced preoperative and intraoperative imaging tools and adjuncts, such as portal vein embolisation, chemoembolisation and ablative therapies.[13]

LIVER TRANSPLANTATION

Liver transplantation is a specialised subdivision of liver surgery and must only be performed in a transplant unit. Liver transplantation has become the standard of care for decompensated end-stage liver disease and for some patients with acute liver failure not responding to aggressive non-surgical management. The common indications for liver transplant in the



12.13 Minimally invasive liver resection. (a) Port positions for laparoscopic right hepatectomy. (b) A robotic liver resection in progress. ⏎

adult population include chronic liver disease secondary to alcoholic liver disease, metabolic liver disease, chronic infections with hepatitis B or C viruses, vascular disorders such as Budd–Chiari syndrome and cholestatic disorders including primary biliary cholangitis and primary sclerosing cholangitis. Biliary atresia and certain metabolic liver disorders are the common indications for liver transplant in the paediatric age group. Highly selected patients with hepatocellular carcinoma (HCC), within the accepted criteria, may be suitable for liver transplant.

SURGICAL CONCEPTS IN LIVER TRANSPLANTATION

Unlike renal allograft, a liver allograft has to be placed orthotopically (i.e. in the same position as the native liver). This is essential because, for the allograft liver to function and maintain itself, it needs to receive the portal flow containing growth factors from the gut. There are four basic steps in liver transplantation:[14]

1. Procurement of the liver allograft
2. Removal of the native diseased liver (explant hepatectomy)
3. Fashioning the liver allograft for implantation (bench work)
4. Implantation of the allograft into the recipient in an orthotopic position

Depending on the source of the liver allograft, liver transplantation is one of two types:

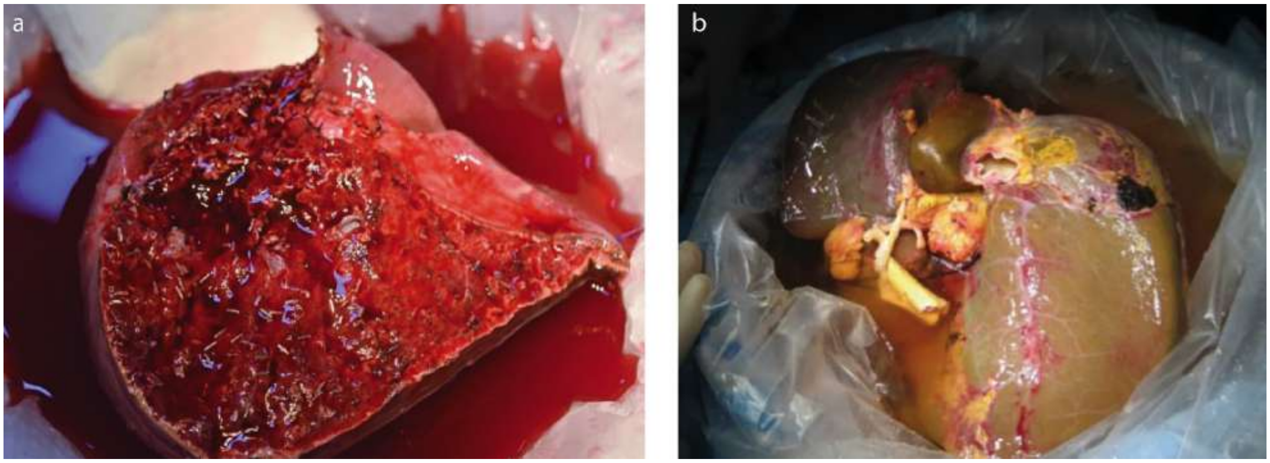
1. *Living donor liver transplant* – part of a liver taken from a healthy voluntary donor is used as the allograft (Figure 12.14a)
2. *Deceased donor liver transplant* – a whole liver allograft that comes from a dead person, after either brain death or cardiac death (Figure 12.14b)

Implantation of liver allograft

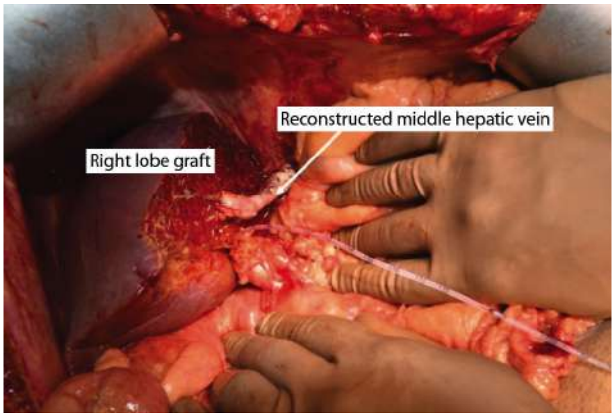
Liver allograft implantation is performed after removal of the native liver. It essentially involves the restoration of vascular inflow and outflow along with biliary outflow of the liver allograft. However, there are technical differences between the implantation of a deceased donor graft and that of a living donor graft.[15]

In a deceased donor liver transplant, two techniques are commonly employed for implantation:

1. *Classical technique*. In this method, the native diseased liver is removed along with the retrohepatic IVC. The graft suprahepatic IVC is then anastomosed to the recipient IVC followed by anastomosis of the graft infrahepatic IVC to the recipient infrahepatic IVC, thus restoring the IVC continuity. This is followed by portal vein, arterial and biliary anastomoses.
2. *Piggyback technique*. In this technique, the native IVC is preserved during explant hepatectomy. The advantage of this technique is that cross-clamping of the recipient IVC is not required, thereby maintaining the venous return to the heart, leading to better intraoperative haemodynamic stability and a reduced incidence of renal injury secondary to renal congestion. During implantation, the infrahepatic IVC opening in the graft is closed while the graft suprahepatic IVC opening is anastomosed to the common cuff of the recipient middle and left hepatic veins (after horizontal extension). The



12.14 Types of liver allografts used in liver transplantation. (a) Living donor right lobe graft. (b) Deceased donor whole liver graft. ⏎



12.15 Right lobe graft following reperfusion. ⏎

portal, arterial and biliary anastomoses are performed in the usual manner.

Implantation of a living donor graft

Implantation of a living donor graft is technically a greater challenge than implantation of a deceased donor graft. This technical complexity is essentially due to the greater number of vascular anastomoses that need to be performed and the fine calibre of hepatic arteries and bile ducts available for anastomoses. Implantation of a right lobe graft involves the following anastomoses (Figure 12.15):

- Grafting the right hepatic vein to the recipient right hepatic vein after side clamping of IVC
- Grafting the reconstructed middle hepatic vein to the stump of the recipient middle hepatic vein–left hepatic vein junction
- Grafting the right portal vein to the recipient main portal vein
- Grafting the right hepatic artery to the recipient right or left hepatic artery
- Grafting the bile duct to the recipient common bile duct

POSTOPERATIVE AND POST-LIVER-TRAUMA COMPLICATIONS

The emphasis of management of liver trauma has shifted in favour of a more conservative approach. Often, no action is required other than careful monitoring, with the infrequent addition of radiological endovascular intervention. Any surgery is usually restricted to packing of the liver to control bleeding, but the occasional patient requires either an emergency resection for uncontrollable haemorrhage or a later intervention for a post-traumatic complication, such as removal of a devascularised and necrosed part of the liver. The range of complications following trauma is similar to those that may be encountered after liver surgery, and they will therefore be considered together in this section.

There are three principle complications following liver surgery: haemorrhage, haemobilia and bile leak.

HAEMORRHAGE

Early post-traumatic and postoperative haemorrhage can often be managed expectantly with the replacement of blood products. However, a coagulopathy must first be excluded or corrected. If time allows and there is radiological expertise available, significant haemorrhage is best managed by angiography and embolisation of a bleeding artery. If the patient is haemodynamically unstable or interventional radiology is not available, then a laparotomy is mandatory. In the trauma situation, packing of the liver is advised. In contrast, in early haemorrhage after surgical resection, oversewing of bleeding points is necessary. Secondary postoperative or post-traumatic haemorrhage is often associated with infection. The tissues are extremely friable and the only surgical intervention possible is usually packing of the bleeding area. Angiography and embolisation of the bleeding vessel is therefore preferred in such situations.[16]

HAEMOBILIA

Haemobilia – haemorrhage into the biliary tree – may follow trauma, surgery, liver biopsy or any other radiological intervention on the liver, and it can also be a complication of almost any hepatobiliary pathology. Haemobilia implies the existence of a fistula between a vessel and a bile duct and usually results from the erosion of a pseudoaneurysm into the biliary tree. Subsequent bleeding is into the gastrointestinal tract through the duodenal ampulla. A bleed may be major, with haematemesis and melaena, or persistent and of low volume, resulting in anaemia. Diagnosis is initially one of exclusion of other sources of gastrointestinal blood loss. Haemobilia is sometimes confirmed if blood is seen at endoscopy to be coming from the duodenal ampulla. Angiography can be confirmatory in showing the anatomical site of the fistula. However, if there is no active bleeding at the time of the examination, the angiogram may be normal, although an area of abnormal vascular anatomy may still be demonstrated. Angiographic embolisation of the bleeding vessel is the definitive treatment in most cases.

BILE LEAK

In practice, the majority of bile leaks occur immediately after liver resection and are managed expectantly by leaving the drain placed at operation *in situ*. Bile in the peritoneal cavity must be drained by percutaneous image-guided placement of a drain or, if this service is unavailable, by laparotomy. If bile is draining through a drain left at the time of surgery, imaging (preferably a CT scan or MRI) must be used to establish that the drain is draining *all* of the leaking bile and that there is no additional collection. The majority of post-surgical bile leaks will seal spontaneously, and a steady reduction in the volume that is draining is reassuring. The management of larger-volume leaks that fail to close depends on the underlying problem. Biliary imaging is necessary to define the anatomy of the leak and exclude biliary obstruction distal to the leak that is preventing spontaneous closure. Leaks from peripherally situated ducts will close spontaneously. Persistent or high-volume leakage usually results from injury to larger ducts and this may require endoscopic retrograde cholangiopancreatography (ERCP) stenting or a sphincterotomy to reduce biliary pressure. Biliary reconstruction may have to be considered at a later date. Attempts at suture closure of a leaking duct result in failure in the majority of cases. A Roux-en-Y hepaticojejunostomy is the procedure of choice for management of a persistent external biliary fistula. The need for this major intervention is fortunately uncommon, as most bile leaks after trauma or resection settle with optimal conservative management.[17]

POST-HEPATECTOMY LIVER FAILURE

This is the most dreaded complication that can occur after a major liver resection. Due to its remarkable regenerative capacity, up to 75% of the volume of a healthy liver can be resected. In general, only if the resected volume is less than 50% can the risk of post-resection liver failure be virtually disregarded. Post-resection hepatic insufficiency is of particular concern after extended left or right hepatectomy. The risk of post-resection liver failure is minimal if most of the specimen volume has been replaced by tumour mass, as compensatory hypertrophy of the uninvolved liver has already taken place.[18] The risk of post-hepatectomy liver failure is significantly greater following resection on cirrhotic, steatotic and post-chemotherapy livers and it can occur despite sufficient liver volume of the remnant liver. This is because liver function and regenerative capacity are often compromised in diseased livers.

Post-hepatectomy liver failure is defined as postoperatively acquired deterioration in the ability of the liver to maintain its synthetic, excretory and detoxifying functions and is characterised by rising serum bilirubin and INR on postoperative day 5. In addition to jaundice and coagulopathy, patients may go on to develop hepatic encephalopathy.

In the absence of any specific therapy, treatment of post-hepatectomy liver failure involves organ support, prevention and treatment of infections in addition to nutritional support. Cross-sectional imaging is very helpful in the management of this condition. Imaging can pick up intra-abdominal biliary collections that can be drained percutaneously. Vascular complications, such as venous thrombosis and associated liver necrosis, which may be the underlying cause of liver failure, are well demonstrated on a contrast CT.[19]

SURGERY FOR LIVER INFECTIONS

PYOGENIC LIVER ABSCESS

This incorporates solitary and multiple collections of pus in the liver resulting from bacterial infection. The infection may reach the liver via the portal vein (portal pyaemia), the hepatic artery, the bile ducts or adjacent organs or from liver trauma.

Portal pyaemia can result from any intra-abdominal infectious or inflammatory condition such as appendicitis, diverticulitis or Crohn's disease. It can also be a manifestation of a gastrointestinal malignancy. Other conditions associated with pyogenic liver abscess include bacterial endocarditis, diabetes, alcoholism and local treatment of liver tumours, and it may also be seen in patients with any immunosuppressed state.

The presenting symptoms are generalised nonspecific symptoms such as fever, fatigue, loss of appetite and abdominal pain. Ultrasound is the first diagnostic modality. It is readily available and sufficient to diagnose an abscess in most cases, but may miss smaller abscesses. Cross-sectional imaging in the form of a contrast CT or MRI should therefore be performed. These modalities have the advantage of detecting other intra-abdominal conditions.

Treatment of a pyogenic liver abscess includes drainage of the abscess, adequate antibiotic therapy and treatment of the underlying condition. Drainage of the abscess is performed by placing ultrasound-guided percutaneous drains. Initially, broad-spectrum and, later, culture-based antibiotics are administered for at least 4–6 weeks. In patients with multiple small abscesses that cannot be drained percutaneously, a prolonged course of culture-based antibiotics is the mainstay of treatment.

There is a limited role for surgical intervention in patients with a pyogenic liver abscess. Intraperitoneal rupture of an abscess is best treated with laparoscopic lavage and drainage. Surgical drainage may also be performed when surgery is required for the underlying intra-abdominal pathology, such as gastrointestinal malignancy or bowel perforation. Laparoscopic drainage and debridement may be required for multiloculated abscesses containing thick pus and necrotic material. Liver resection may rarely be required for multiple chronic abscesses confined to one part of the liver, usually resulting from segmental bile duct obstruction.

AMOEBIC LIVER ABSCESS

This is the most common extraintestinal manifestation of infection with the protozoan *Entamoeba histolytica*. Simultaneous presentation of amoebic colitis and amoebic liver abscess is uncommon. Fever with chills, right upper abdominal pain, fatigue and weight loss are common symptoms. Unlike in a pyogenic liver abscess, an amoebic liver abscess is usually solitary and located in the right posterior superior quadrant of the liver. Ultrasound is a good diagnostic modality, and cross-sectional imaging has little advantage over ultrasound in uncomplicated cases. Amoebic serology has a high sensitivity and specificity for differentiating amoebic from pyogenic liver abscess. Anti-amoebic antimicrobial therapy is the mainstay of treatment in the majority of the cases. Therapeutic ultrasound-guided aspiration, or drainage, is indicated only for older patients, patients with comorbidities, large abscesses (>5 cm) and the failure of antimicrobial therapy after 5–7 days of treatment. There is a limited role for laparotomy or laparoscopic intervention for an amoebic liver abscess. Absolute indications for surgical intervention include a doubtful diagnosis, concomitant hollow viscus perforation, peritoneal rupture and failure of non-operative treatment.

HYDATID DISEASE

Hydatid disease is caused by *Echinococcus* spp., a parasite whose life cycle passes alternately through dogs and sheep. In sheep, it is within visceral cysts, while, in dogs, it is a small intestinal worm. Humans become accidental intermediate hosts when they acquire the infection after the ingestion of ova passed in dog faeces. The incidence of the disease thus shows great occupational and geographical variation. *E. granulosus* and *E. multilocularis* are the two species commonly associated with human infection. The latter is more aggressive and requires a more radical approach to management. One or more cysts containing viable parasites develop in the liver. They grow slowly and therefore remain asymptomatic for years. Symptoms depend on the site and size of the cysts. Large cysts may cause pain or jaundice from pressure. Secondary infection and rupture into the biliary or bronchial tree or into the peritoneum are serious complications.[9]

Diagnosis of hydatid liver disease is based on clinical and epidemiological history, imaging and serological tests. Ultrasound is the initial screening modality. The World Health Organization classification of hydatid liver cysts is based on the ultrasound appearance of the cyst. CT scan and MRI should be performed before deciding on the treatment approach.

There are three goals of ideal treatment of hydatid disease: (1) removal of the parasite, (2) removal of the residual cavity and (3) identification and treatment of any biliary communication. There are three commonly used treatment modalities: surgery, percutaneous interventions and medical treatment with benzimidazoles.

Surgery for hydatid cysts is indicated for large multiloculated cysts, superficially located cysts and complicated cysts. Surgery is not indicated for asymptomatic inactive (calcified) cysts, very small cysts and difficult-to-access cysts. The surgical approach can be open or minimally invasive. Surgery for hydatid disease of the liver can be either conservative or radical. The most commonly performed conservative procedure is ‘cystectomy’. This procedure includes cyst aspiration, injection of scolicidal agent (10% hypertonic saline) if cyst contents are not bilious in nature, cyst decompression by re-aspiration, hydatidectomy or removal of cyst contents by incising the protruding cyst wall, suture ligation of any cyst–biliary communications, deroofing of the protruding cyst wall and obliteration of the residual cyst cavity by packing with omentum (omentoplasty). Cystectomy is a simple procedure but carries risks of the spillage of cyst contents and dissemination of disease into the peritoneal cavity.

Radical surgical procedures for hydatid disease include total pericystectomy (cystopericystectomy) and liver resection. These procedures achieve all of the objectives of hydatid surgery but are technically demanding.

Percutaneous procedures are indicated for large (>5 cm) uniloculated cysts or cysts with floating membranes. The classical percutaneous procedure is ‘PAIR’, an acronym that stands for percutaneous puncture, aspiration of cyst contents, injection of scolicidal agent and re-aspiration of cyst fluid. Modifications of this procedure include PAIR catheterisation, in which a catheter is left in the cyst cavity for 24 hours, and percutaneous aspiration of cyst contents (PEVAC).

Alveolar echinococcosis is a more aggressive disease that spreads like a slowly infiltrative liver cancer. Radical liver resection is the treatment of choice. When there is bilobar involvement of the liver, liver transplantation is recommended. Palliative surgery in the form of debulking surgery is performed when the above two surgical approaches are not feasible.

RECURRENT PYOGENIC CHOLANGITIS

Also known as oriental cholangiohepatitis, this is a chronic infective process of the biliary tree, presenting primarily with recurrent attacks of acute bacterial cholangitis. The hallmark of this disease process is primary hepatolithiasis, that is, the formation of multiple intraductal calculi in the absence of extrahepatic biliary obstruction. Chronic infections with helminths such as *Clonorchis sinensis* and *Ascaris lumbricoides* have been shown to be associated with recurrent pyogenic cholangitis. Patients with recurrent pyogenic cholangitis typically present with a spectrum of illness severity, ranging from mild symptoms to fulminant abdominal sepsis. MRCP is the gold standard non-invasive imaging modality for the diagnosis of recurrent pyogenic cholangitis. Definitive treatment of recurrent pyogenic cholangitis for those who do not respond to medical management is in the form of biliary decompression. Initially, ERCP is used both to characterise the extent of disease and to provide therapy such as stone removal, sphincterotomy or stent insertion for visible and accessible strictures for more distal obstructions. Percutaneous biliary decompression is preferred for more peripherally located calculi. If the disease is anatomically limited (typically to the left lobe), surgical resection of the involved liver and of the extrahepatic bile duct with reconstruction should be undertaken. Surgery, in the form of a major hepatic resection, is also indicated in severe cases where extensive hepatic parenchymal destruction or multiple abscesses are present or when a CCA has been detected.[20]

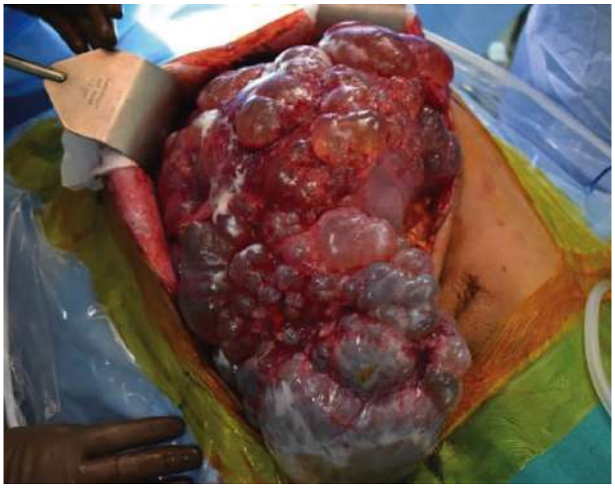
NON-INFECTIOUS LIVER CYSTS

SIMPLE CYSTS

Single or multiple liver cysts are often incidentally discovered on screening ultrasound or cross-sectional imaging performed for some other indication or they may be found during laparotomy or laparoscopy. There is sometimes initial diagnostic uncertainty and concern about malignancy. Small asymptomatic cysts require no treatment. The occasional cyst may grow to a large size, compress the surrounding liver and distort the vascular or biliary anatomy. Pain and, less commonly, jaundice precipitate intervention. Percutaneous aspiration should not be attempted, as the cyst invariably re-accumulates and may bleed or become infected. Total excision by cystectomy or, more satisfactorily, by a formal liver resection is preferred. Conservative surgery, whether fenestration or marsupialisation, is often disappointing, as recurrence is likely if a significant portion of the cyst wall is left *in situ*. However, cysts that hang off the inferior aspect of the liver may be managed by laparoscopic deroofing as long as the majority of the cyst wall can be easily removed.

POLYCYSTIC LIVER DISEASE

This is a genetic disorder characterised by the development of multiple cysts in both lobes of the liver. It may occur in isolation or may be associated with autosomal dominant polycystic kidney disease. Most patients remain asymptomatic. However, in some patients, as a consequence of multiple large cysts in both lobes of the liver, massive hepatomegaly occurs, leading to pressure symptoms such as abdominal fullness, discomfort, shortness of breath, early satiety and pedal oedema (Figure 12.16). Complications include intra-cystic bleeding, infection and portal hypertension with ascites due to hepatic vein or portal vein compression. Polycystic liver disease can be easily diagnosed on a screening ultrasound, but cross-sectional imaging is essential for surgical planning. Treatment is required only in symptomatic patients and can range from laparoscopic (or open) fenestration when there are a limited number of large symptomatic cysts to liver resection when there are large areas requiring parenchymal-sparing surgery, extending to liver transplantation when there is diffuse involvement of the entire liver.[9] Liver transplantation remains the only curative treatment for this benign condition.



12.16 Polycystic liver disease. ⏎

CYSTIC DILATATION OF INTRAHEPATIC BILE DUCTS

Congenital intrahepatic bile duct dilatation without underlying liver fibrosis is called Caroli's disease and, when associated with fibrotic or cirrhotic liver morphology, is called Caroli's syndrome. Caroli's disease and Caroli's syndrome can be limited to a part of the liver or can present as diffuse bilobar involvement. Recurrent cholangitis is the usual presentation. Cirrhosis leading to portal hypertension with its associated complications, such as gastrointestinal bleeding, ascites and hypersplenism, may develop in long-standing cases. CCA is another serious complication seen in some of these patients. Although initial treatment is conservative, consisting of antibiotics and biliary decompression, surgery in the form of liver resection for limited disease and liver transplantation for diffuse Caroli's disease associated with portal hypertension provides excellent long-term outcomes.[21]

SURGERY FOR LIVER TUMOURS

BENIGN NEOPLASMS

The frequent use of medical imaging, including ultrasonography, has led to an increased incidence in the diagnosis of benign liver tumours, most being asymptomatic. Although there is a large variety of solid benign liver tumours of different cellular origins, the most frequent ones are hepatic haemangioma, focal nodular hyperplasia and hepatocellular adenoma. As imaging techniques improve, a precise diagnosis is possible in most cases obviating the need for a percutaneous biopsy.

Haemangiomas

These are the most common benign neoplasm, with an incidence of 3–20%. Usually solitary and less than 5 cm in size, most haemangiomas are asymptomatic and are diagnosed incidentally. Haemangiomas larger than 10 cm in diameter are labelled giant haemangiomas. Large haemangiomas may cause abdominal pain and discomfort, while pressure symptoms are uncommon. Rupture and bleeding are rare and, therefore, any major lifestyle modifications are not recommended. Asymptomatic haemangiomas need no treatment; larger ones may be followed with serial ultrasound examinations. Surgery in the form of enucleation or liver resection remains the most common treatment modality and is indicated for symptomatic haemangiomas. Non-surgical options include transcatheter arterial embolisation (TAE), which is well suited for treating acutely bleeding haemangiomas and for shrinkage of large haemangiomas prior to surgery.

Focal nodular hyperplasia

This is the second most common benign tumour of the liver and shows high female preponderance. They are usually (85–90%) solitary and less than 5 cm in diameter. A central stellated scar on cross-sectional imaging is very characteristic of focal nodular hyperplasia. This lesion does not carry malignant potential and the majority remain asymptomatic. Surgery in the form of anatomical or non-anatomical resection is indicated for symptomatic focal nodular hyperplasia or when the diagnosis is doubtful and malignancy cannot be ruled out. TAE and radiofrequency ablation are the preferred non-surgical treatment modalities.[22]

Hepatocellular adenoma

This a benign liver tumour that is predominantly found in young and middle-aged women using oral contraceptives or other steroid medications. These are heterogenous lesions that have been divided into six molecular subtypes. Sometimes it can be difficult to differentiate a hepatic adenoma from an HCC. MRI can differentiate between the two entities with a high degree of accuracy. The majority of cases are diagnosed incidentally. Pain is the most common symptom, while complications include bleeding and malignant transformation. The term hepatic adenomatosis is used when multiple (more than three) adenomas are present.

Resection remains the mainstay of treatment. All adenomas in male patients should be resected due to a higher incidence of malignant transformation. In female patients, adenomas larger than 5 cm should be resected, while a trial of observation after cessation of steroid medications can be safely recommended for smaller lesions. TAE is used for the emergency control of bleeding from a hepatic adenoma.[22]

HEPATOCELLULAR CARCINOMA

HCC is the most common primary liver tumour and is the sixth most common malignancy worldwide. Since the majority of HCCs arise on a background of cirrhosis, the geographic distribution varies widely, being most common in South East Asia and sub-Saharan Africa, where the prevalence of chronic hepatitis B infection continues to be high. The majority of cases of HCC arise on a background of underlying chronic liver disease, the common causes of cirrhosis being chronic viral hepatitis (hepatitis B and C), alcohol abuse and non-alcoholic fatty liver disease. Cross-sectional imaging is the mainstay of diagnosis of an HCC. A distinctive pattern of hyperenhancement in the arterial phase and washout in venous or delayed phases on contrast-enhanced CT or MRI has a specificity of more than 90% for diagnosis of HCC in patients with cirrhosis and nodules greater than 1 cm. A histological diagnosis is therefore not required for the diagnosis of HCC in the majority of cases.

Since most patients with HCC have concomitant liver disease, the benefits of treating the tumour must be balanced against the potential harms of medical interventions in patients with cirrhosis. The Barcelona Clinic Liver Cancer (BCLC) algorithm is the most commonly followed staging system and treatment algorithm used for the management of HCC. The tumour burden is assessed based on the number and size of tumour nodules, along with the presence of macrovascular tumour invasion and extrahepatic spread. The degree of underlying liver dysfunction is quantified using the Child–Pugh–Turcotte or MELD scoring systems.

Surgical options for patients with hepatocellular cancer include liver resection (Figure 12.17) and liver transplantation. The ideal candidates for resection are patients with a solitary tumour at an early stage (BCLC stage 0 or A) or, regardless of tumour size, in those whose performance status is good, whose liver function is well preserved and in whom there is no clinically significant portal hypertension. For these patients, resection is associated with survival above 60% at 5 years. Liver transplantation is indicated in patients with a limited tumour burden who are not candidates for resection due to significant liver dysfunction and portal hypertension. In addition to removing the tumour, transplantation has the advantage of curing the underlying liver disease. The Milan criteria for liver transplantation (i.e. a single nodule ≤5 cm in diameter or up to three nodules with none larger than 3 cm in diameter) are the benchmark in selecting patients with HCC for transplantation. Macrovascular tumour invasion or extrahepatic spread is a contraindication for transplantation because of the high risk of tumour recurrence.[23]

Non-surgical treatment modalities for HCC include ablative and transarterial therapies. Radiofrequency ablation is the most commonly used ablative approach and is indicated for small tumours up to 3 cm in diameter. Other ablative therapies include microwave ablation, cryoablation and ethanol injection. Transarterial therapies are indicated for intermediate-stage tumours. Transarterial chemoembolisation entails intra-arterial infusion of a cytotoxic agent, followed immediately by embolisation of the vessels that feed the tumour, while transarterial radioembolisation is based on the intra-arterial infusion of glass or resin microspheres containing the radioisotope yttrium-90. The radiation emitted by yttrium-90 is responsible for its anti-tumour activity. Systemic therapies are recommended for advanced and metastatic tumours.

12.17 Large HCC. ⏎

CHOLANGIOCARCINOMA

CCAs are a heterogeneous group of neoplasms of the bile ducts and represent the second most common hepatic cancer after HCC. They are subclassified as intrahepatic CCA (iCCA) and extrahepatic CCA (eCCA), the latter comprising both peri-hilar CCA (pCCA or Klatskin tumour) and distal bile duct CCA (dCCA).

Hepatobiliary resection is the gold standard and the only potentially curative treatment for CCA; it is indicated for iCCA and pCCA, while the diagnostic workup and treatment of dCCA are more similar to those of cancer of the head of the pancreas. The goal of the surgery is to achieve a radical (R0) resection while preserving adequate function of the FLR. Resectability depends on two main variables: the location of the tumour, including its relationship with intrahepatic vascular and biliary structures, and the amount and quality of the liver parenchyma remaining after tumour resection.[24]

SECONDARY LIVER TUMOURS

Liver metastases are commonly detected in a range of malignancies, including CRC, neuroendocrine tumours, gastrointestinal stromal tumours, pancreatic cancer, melanoma, lung cancer, breast cancer, renal cell cancer and prostate cancer. However, CRC is the most common primary cancer that metastasises to the liver. Interactions between tumour cells and the tumour microenvironment play an important part in the liver seeding, survival and progression of the metastases.

Colorectal liver metastases (CRLMs) are the primary driver of disease-specific mortality in patients with CRC. Imaging plays a vital role in adequately identifying and characterising the extent of disease within the liver, defining relevant anatomy, estimating the remnant liver volume and, importantly, identifying extrahepatic disease that may often preclude hepatectomy. Historically, ultrasonography was the method of choice to identify CRLM; however, it has now been replaced by cross-sectional imaging modalities such as CT, MRI and positron emission tomography (PET)-CT, which have high accuracy in the detection of occult lesions and better delineation of hepatic anatomy.

The management of CRLMs requires a multimodality approach, although surgical resection remains the mainstay of CRLM therapy and is the only potentially curative treatment.[25] The current guidelines for the resection of CRLM recommend the removal of all macroscopic disease with negative margins while leaving sufficient functioning liver. Risk scores such as the Fong Clinical Risk Score have been proposed to define oncological resectability. A combination of parenchymal-preserving resection and ablation techniques, neoadjuvant therapy to downsize tumours, and strategies to increase hepatic reserve have expanded the criteria of resectability to include any patient in whom all disease can be removed with a negative margin and sufficient FLR. As such, the determination of resectability is a highly nuanced and individualised approach and is optimally assessed by an experienced hepatic surgeon.

In patients with synchronous liver metastases, a liver resection can be carried out at the same time as the bowel resection, except when liver and bowel resections are major procedures. For example, a right hemicolectomy can be combined with a right hepatectomy and an anterior resection with a left lateral sectionectomy, but if a patient requires an anterior resection and a right hepatectomy, the liver resection should generally be deferred for a staged second operation.

FLR AUGMENTATION STRATEGIES

Although an FLR of approximately 25–30% is generally considered to be sufficient to maintain liver function in patients with an otherwise normal liver, a larger future remnant liver is recommended for patients with chemotherapy-associated steatohepatitis to avoid post-hepatectomy liver failure. Several strategies have been developed for this purpose.

PORTAL VEIN EMBOLISATION

Embolisation of the portal vein on the side of the liver to be resected leads to atrophy of the ipsilateral side and hypertrophy (30–50%) of the contralateral side. However, it usually takes 4–6 weeks for the hypertrophy to occur, and there is always a possibility that the metastases may progress during the waiting period.

TWO-STAGE HEPATECTOMY WITH PORTAL VEIN LIGATION

This technique involves resection of the less affected side along with portal vein ligation on the side with major tumour burden in the first stage, followed by resection of the side with the major tumour burden after a 4- to 6-week delay, during which hypertrophy of the FLR occurs.

ASSOCIATING LIVER PARTITION WITH PORTAL VEIN LIGATION FOR STAGED HEPATECTOMY

Associating liver partition with portal vein ligation for staged hepatectomy (ALPPS) is a combination of portal vein ligation and *in situ* liver parenchyma transection performed during the first stage, followed by removal of the diseased side in the second stage, usually after an interval of 7–10 days. This technique triggers a rapid regeneration of the FLR and reduces the interval between the stage 1 and 2 hepatectomies from 4–6 weeks to only 7–14 days.[8,9] Despite an up to 80% reduction in the time needed to allow for sufficient FLR hypertrophy compared with portal vein embolisation or portal vein ligation alone, ALPPS has been criticised due to concerns over high morbidity and mortality rates of up to 25%.

SURGERY FOR PORTAL HYPERTENSION

Surgical management of portal hypertension is now mainly historical. Portal hypertension is caused by obstruction to venous drainage of the portal circulation. This may be post-hepatic from hepatic venous thrombosis in Budd–Chiari syndrome, intrahepatic from cirrhosis, or prehepatic from obstruction of the portal vein. Whatever the aetiology, the pressure within the portal venous system rises and collateral channels open up between the portal and systemic venous beds. Many of these channels, such as those in the retroperitoneum, are harmless, but those at the gastric cardia produce gastro-oesophageal varices, which can present with torrential gastrointestinal haemorrhage. Historically, surgery for portal hypertension was focused either on interrupting the portosystemic venous collaterals at the cardia or on the reduction of portal pressure.

Interruption of the portosystemic venous collaterals at the gastro-oesophageal junction is achieved by a set of procedures broadly termed as 'devascularisation' procedures, while reduction of portal pressures is achieved by the creation of portosystemic shunts either surgically or, as is the current practice, by a minimally invasive technique called transjugular intrahepatic portosystemic shunt (TIPS).

DEVASCULARISATION PROCEDURES

These procedures aim to control bleeding from gastro-oesophageal varices and have a role in emergency control of acute variceal bleeding when other non-operative methods have failed or are not feasible. They are also indicated in cases of non-cirrhotic portal hypertension and extrahepatic portal venous obstruction (EHPVO) when the vascular anatomy is not suitable for a portosystemic shunt procedure. These procedures are, however, contraindicated in patients with compromised liver function. The well-known devascularisation procedures are Hassab's procedure, the Sugiura and Futagawa procedure, and shunt procedures.

Hassab's procedure

In this procedure, gastro-oesophageal devascularisation is done without oesophageal transection and pyloroplasty. Splenectomy is also a part of the procedure.[9]

Sugiura and Futagawa procedure

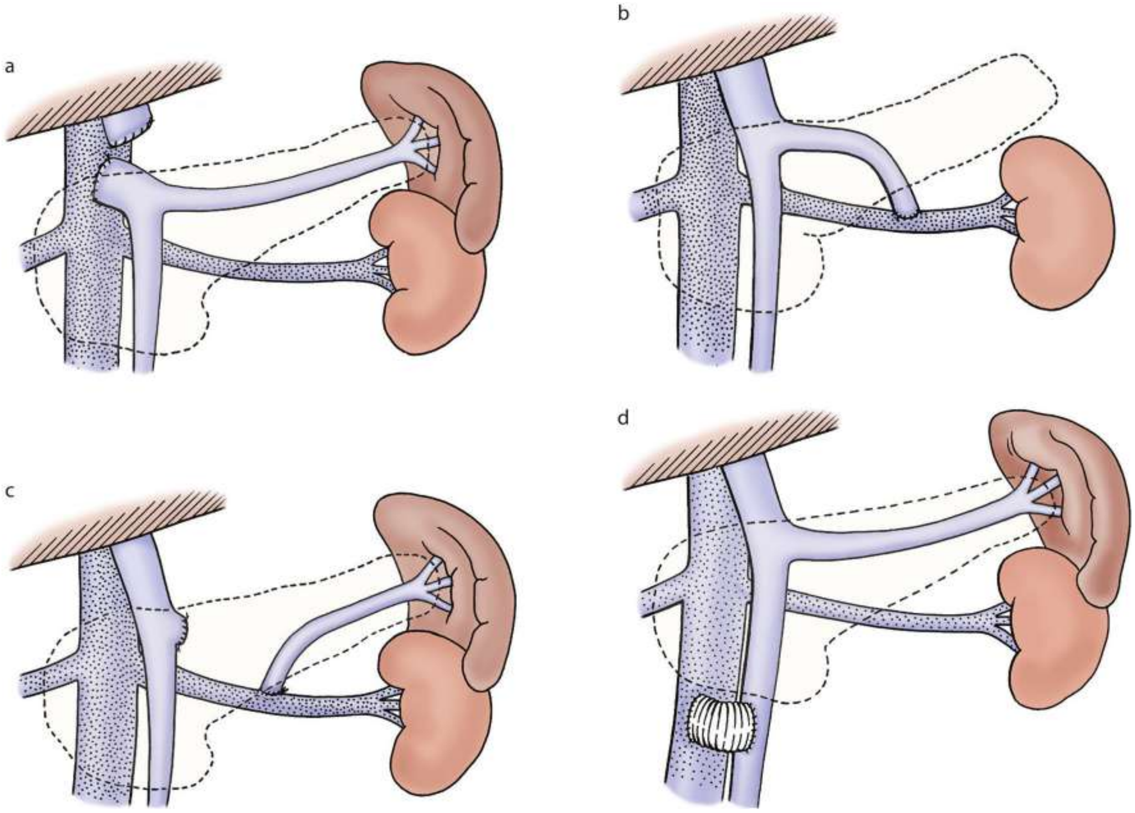
This procedure was originally described in two parts, namely the thoracic part – which involves para-oesophageal devascularisation for a length of about 10 cm and oesophageal transection and anastomosis – and the abdominal part, which includes devascularisation of the abdominal oesophagus, cardia and greater curvature of the stomach, selective vagotomy and pyloroplasty. This procedure was considered too complex and was therefore modified subsequently. The modifications include performing the entire procedure via the abdominal approach and using staplers for oesophageal transection. The entire procedure can also be performed using a minimally invasive approach.[9]

SHUNT PROCEDURES

These procedures control variceal bleeding by decompressing the portal circulation by creating a portosystemic bypass. Emergency shunt surgery has now been almost completely replaced by endoscopic and TIPS procedures. Even in the elective setting, shunt surgery is only occasionally performed in patients with non-cirrhotic portal hypertension or EHPVO for control of recurrent variceal bleeding after failure of less invasive methods or for control of ascites in patients with Budd–Chiari syndrome. Shunts can be classified as non-selective, partial or selective, depending on whether they divert the portal flow completely, divert it partially or compartmentalise the portal flow, respectively. The advantage of a partial or selective shunt over non-selective shunts is that they preserve hepatic portal perfusion, thereby minimising the risk of progressive hepatic failure and encephalopathy while controlling variceal bleeding. The different types of non-selective shunts are:

- End-to-side and side-to-side portocaval shunt
- Interposition mesocaval shunt
- Proximal and central splenorenal shunts (Figure 12.18)

The classical example of a selective shunt is the distal splenorenal or the Warren shunt, while the interposition (8 mm polytetrafluoroethylene [PTFE] graft) is interposed between the portal vein and the IVC. A portocaval or Sarfeh shunt is an example of a partial shunt.



12.18 Portocaval splenorenal shunts. (a) An end-to-side portocaval anastomosis. (b) Proximal splenorenal shunt with splenectomy. (c) Warren distal splenorenal shunt. (d) Mesocaval shunt with a Dacron 'H' graft. ⏎

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Emergency small and large bowel surgery and surgery for benign disease

13

James Hollingshead and Cecil T Thomas

ANATOMY

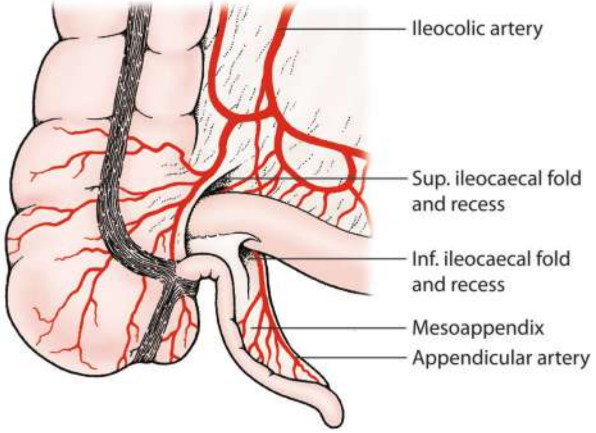
THE SMALL INTESTINE

The *jejunum* begins as a direct continuation of the predominantly retroperitoneal duodenum at the duodenojejunal flexure. Distally, the jejunum is continuous with the *ileum*, with no line of demarcation. The ileum joins the medial wall of the caecum at the ileocaecal valve. The jejunum and ileum have a complete peritoneal covering and lie as free loops in the peritoneal cavity, suspended on the small bowel mesentery. The *mesentery* contains the arteries, veins, lymphatics and nerves of the small intestine between the two peritoneal covered layers. Its root, or line of attachment to the posterior wall, extends obliquely from the duodenojejunal flexure to the caecum.

THE LARGE INTESTINE

An understanding of the surgical anatomy of the colon is dependent on an appreciation of the intrauterine folding and rotation of the gastrointestinal tract, which is outlined in the embryology section in Chapter 7.

The *caecum* normally occupies the right iliac fossa; it is completely enveloped in peritoneum but has no mesentery, so it is relatively fixed in position. The *appendix* is attached to the posteromedial aspect, just below the ileocaecal junction, and the three taeniae coli of the caecum converge to end at the base of the appendix. The appendix is variable in position but most commonly lies retrocaecally or, less frequently, lies with the tip free in the pelvis. A retrocaecal appendix may lie retroperitoneally, but in most cases the appendix has a complete peritoneal covering and its own mesentery, containing the appendicular artery (Figure 13.1). An additional avascular fold of peritoneum extending from the front of the terminal ileum to the proximal appendix may be present.


Ileocolic artery
Sup. ileocaecal fold and recess
Inf. ileocaecal fold and recess
Mesoappendix
Appendicular artery

13.1 Anatomy of the appendix and ileocaecal region. ⏎

The *ascending colon* is bound down to the posterior abdominal wall and is covered with peritoneum only on its anterior surface and sides. The *hepatic flexure* lies on the right kidney and the second part of the duodenum. The *transverse colon* is again freely mobile, since it has a complete peritoneal investment and a mesentery. A long transverse colon may hang down into the pelvis, but is easily distinguishable from the sigmoid colon by the attachment of the greater omentum to its lower border. The complex peritoneal folds around the transverse colon are easier to understand from an embryological viewpoint. At the *splenic flexure*, the colon is again bound to the posterior abdominal wall, overlies the left kidney and is closely related to the spleen, which lies superolateral to the splenic flexure. The *descending colon* is related to the posterior abdominal wall in a similar fashion to the ascending colon. The colon again becomes mobile on a mesentery as the *sigmoid* (or *pelvic*) *colon*. The sigmoid colon is of variable length and mobility and, as its mesenteric extremity points lie fairly close together, it is liable to volvulus. The large intestine again becomes fixed and finally totally retroperitoneal as the rectum.

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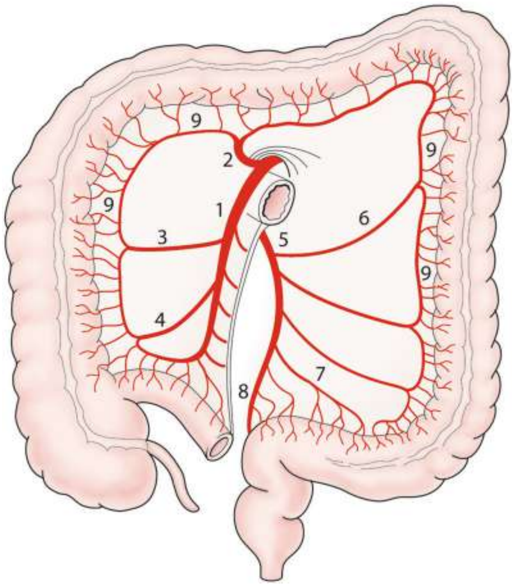
The *rectosigmoid junction* has been defined as opposite the third segment of the sacrum, as the point where the taeniae spread out to form a continuous longitudinal muscle layer, and as a measured distance from the anal verge. The distance used for the definition of this rather artificial junction, and hence the length of the rectum, has varied from 12 to 15 cm from the anal verge. Standardisation is important for communication between surgeons with regard to the treatment of rectal and sigmoid cancer, but there is no absolute universal definition. Most surgeons adopt an arbitrary definition of the junction between the sigmoid colon and rectum being 15 cm from the anal verge, when measured using a rigid sigmoidoscope in an awake patient in the left lateral position.

The *rectum* lies in the concavity of the sacrum and ends by making an acute posterior angulation to become the anal canal. The upper third of the rectum is covered with peritoneum anteriorly and on both sides; the middle third is covered only in the front, while the lower third is entirely devoid of peritoneum, as it lies below the pelvic peritoneum. Below the peritoneal reflection, the rectum is related anteriorly in the male to the base of the bladder, the seminal vesicles and the prostate and is separated from them by Denonvilliers' fascia. This fascial layer may represent the fused anterior and posterior peritoneum of the deeper rectovesical pouch, which was present during embryological development. In the female, the rectum is related anteriorly to the posterior vaginal wall, with a thin rectovaginal septum between the rectum and vagina. The rectum has its own discrete 'mesentery' or *mesorectum*, which encircles the rectum, but the bulk of the mesorectum lies posteriorly in the concavity of the pelvis. There is an areolar plane (the mesorectal fascia or 'holy plane' described by Bill Heald) between the mesorectum and the structures of the pelvic sidewall. This was not initially appreciated, but is of great importance in the surgery of rectal cancer.

BLOOD SUPPLY

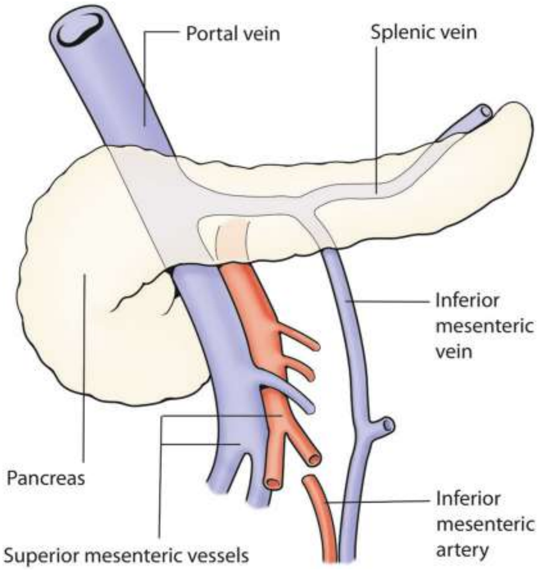
The small and large bowel are supplied almost exclusively by branches of the *superior* and *inferior mesenteric arteries*. The jejunal and ileal branches of the superior mesenteric artery run in the small bowel mesentery. Three main branches from the superior mesenteric artery supply the large bowel proximal to the splenic flexure. The middle colic artery runs in the transverse mesocolon and the right colic and ileocolic arteries are retroperitoneal as they run towards the ascending colon and caecum (Figure 13.2).

The inferior mesenteric artery runs a retroperitoneal course but, after full mobilisation of the sigmoid colon, it can be appreciated that, in reality, it is lying posteriorly within the pelvic mesocolon. It supplies the large bowel distal to the splenic flexure via the ascending left colic artery, the sigmoid arteries and its own continuation as the superior rectal artery into the mesorectum. The rectum also has a blood supply from the inferior rectal (haemorrhoidal) arteries, but the middle rectal arteries, which are described in older anatomy texts, are small and often absent. The arterial vasculature within the large bowel mesentery is arranged in a series of loops with interconnecting anastomoses. The large anastomotic channel close to the bowel is the *marginal artery*. It is this arterial anatomy that makes many large bowel resections possible and enables the surgeon to sacrifice the inferior mesenteric artery in infrarenal aortic prosthetic replacement surgery, with only infrequent compromise to left colonic arterial perfusion.



13.2 The arterial supply of the large bowel. 1, superior mesenteric; 2, middle colic; 3, right colic; 4, ileocolic; 5, inferior mesenteric; 6, ascending left colic; 7, sigmoid arteries; 8, superior rectal; 9, the 'marginal' artery, which consists of anastomotic arterial loops between individual arteries. The marginal artery may form an inadequate anastomotic channel at the watershed between the supply from the superior and inferior mesenteric arteries around the splenic flexure. ⏎

The venous drainage of the intestines initially follows the arteries. The *superior mesenteric vein* lies on the right side of the superior mesenteric artery until it unites with the splenic vein to form the portal vein behind the neck of the pancreas. The *inferior mesenteric vein* lies lateral to the inferior mesenteric artery and, as it ascends above the level of origin of the artery, it lies progressively more lateral. It disappears behind the pancreas lateral to the duodenojejunal flexure to join the splenic vein (Figure 13.3).



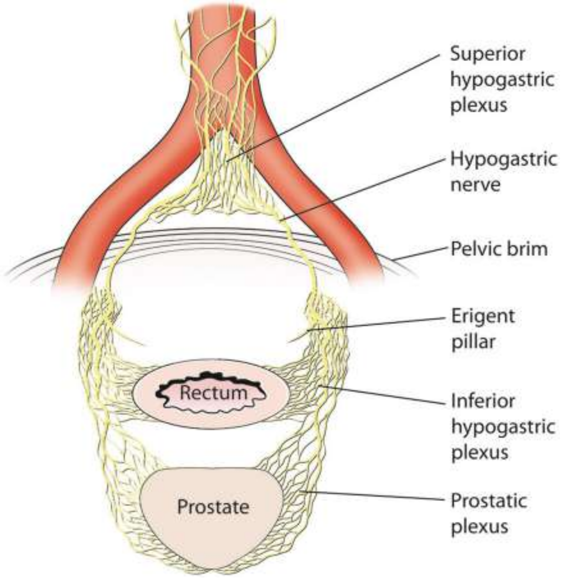
13.3 Venous drainage of the bowel. The veins are lateral to the arteries. ⏎

LYMPHATIC DRAINAGE

The lymphatic drainage of the intestines follows the arterial supply. The only exception is the rectum. Although the rectum has an arterial contribution from the inferior rectal arteries, its lymphatic drainage is almost exclusively upwards alongside the superior rectal artery and finally into the preaortic lymph nodes. However, some patients have lymphatic drainage to the lateral pelvic sidewall, and this may account for pelvic sidewall nodal spread in some patients, particularly those with low rectal cancers.[1]

PELVIC AUTONOMIC NERVES

The multiple sympathetic fibres of the *superior hypogastric plexus* lie over the anterior surface of the aortic bifurcation and the left common iliac vein. They condense to form the two hypogastric nerves, which diverge as they cross the brim of the pelvis to the pelvic sidewall, where each merges with the parasympathetic outflow from S2, 3 and 4 to form the *inferior hypogastric plexus* (Figure 13.4). This combined autonomic plexus lies as a fenestrated plaque on the pelvic sidewall. The largest parasympathetic contribution to the inferior hypogastric plexus is from S3, and this erigent nerve can be demonstrated during pelvic surgery as a sidewall pillar running up to the plexus. Anteriorly, the inferior hypogastric plexi turn medially and finally coalesce anteromedially on the anterior surface of Denonvilliers' fascia as the *prostatic plexus* in the male. In the female, the nerve projections of the inferior hypogastric plexi run anterior to the double-layered vesicovaginal fascia on route to the urinary bladder.[2]



13.4 The superior hypogastric plexus on the front of the aorta and the common iliac vein, the two hypogastric nerves at the pelvic brim, the inferior hypogastric plexus on the pelvic sidewalls and the prostatic plexus lying on the anterior surface of Denonvilliers' fascia are all at risk in rectal surgery. ⏎

The parasympathetic and sympathetic innervation of the pelvic organs is by small nerves from these pelvic autonomic plexi. Autonomic innervation of the bladder and sexual organs in males is from the prostatic plexus anterior to the rectum. Sympathetic innervation is essential for ejaculation and parasympathetic innervation is essential for erection. Rectal autonomic innervation is from both inferior hypogastric plexi. The small rectal branches cross the areolar plane, between the parietal structures in the pelvis and the visceral contents, to enter the mesorectum. These nerves are the only autonomic nerve fibres that are intentionally sacrificed when the rectum is mobilised by dissection on the surface of the mesorectum. All other autonomic nerves, although vulnerable to injury, are just outside this anatomical plane.[3]

APPENDICECTOMY

Acute appendicitis is a common surgical emergency and, although medical management is a potential alternative, this has the disadvantage of prolonged hospital stay and an 18% incidence of recurrence.[4] Laparoscopy has been increasingly used in the management of acute appendicitis.[5] The advantages are quicker postoperative recovery, lesser incidence of wound infections and smaller incision scars. The disadvantages are higher hospital cost and a possible small increased incidence of intra-abdominal abscesses.[6]

Laparoscopic appendicectomy has significant advantages in the obese patient, who would otherwise require a substantial incision for adequate access, and in older patients. In pregnancy, in addition to the aforementioned advantages of laparoscopy, there are no significant adverse obstetric outcomes.[7] Laparoscopy also has the advantage of allowing better inspection of the abdominal cavity, and pelvic organs, for other pathology.

LAPAROSCOPIC APPENDICECTOMY

A three-port technique is normally used. The first port is a 10 mm port for the camera and is established at the umbilicus. Additional ports are positioned to give access to the right iliac fossa for dissection. A suprapubic port and a port close to the left anterior superior iliac spine will achieve this. Here, 5 mm ports are adequate for the dissection but mean that the appendix has to be removed through the umbilical port, usually by removing the camera temporarily to insert a bag, which can then be pulled out once the appendix has been placed inside. Inserting a second 10 mm port here rather than two 5 mm ports allows easier specimen extraction, but will require fascial closure. There is a risk of bladder injury with the suprapubic port, and some surgeons advise routine temporary catheterisation to avoid the necessity of catheterising during the procedure if the bladder is found to be distended. The patient is placed in a Trendelenburg position so that the small bowel moves into the upper abdomen. If a normal appendix is seen, other pathology should be sought. If a clear cause for the patient's symptoms is found elsewhere in the abdomen, then it is reasonable to leave the appendix *in situ*, but otherwise an appendicectomy should be carried out, as appendicitis begins as a mucosal inflammation and, in early disease, the serosal surface may still appear normal.

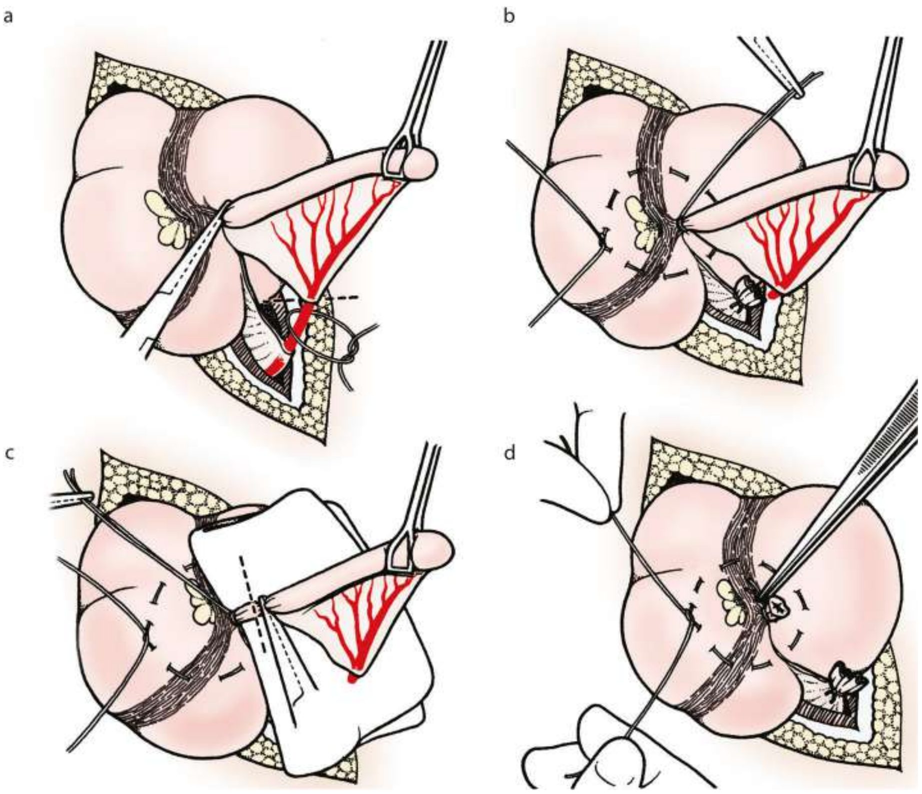
Dissection may be required to bring the appendix into view. Adherent loops of omentum and small bowel can often be gently peeled away using blunt dissection with closed forceps or suction. Grasping and manipulating the bowel directly with laparoscopic graspers should be avoided where possible because of the risk of injury. Adhesions from the appendix to the abdominal sidewall may be divided with diathermy. When the appendix is lying retrocaecally, the first step in the dissection is release of the peritoneum lateral to the caecum so that the appendix can be delivered. The caecum is then retracted upwards to expose the base of the appendix, which can then be picked up. If there is difficulty mobilising the appendix laparoscopically, an early decision to convert to an open operation is prudent.

The appendix and mesentery are divided and secured separately. The appendix mesentery can be divided with diathermy to a point close to the base of the appendix. While this is usually sufficient to control the small vessels within the mesentery, bleeding can occur. This bleeding can be controlled either with a clip or by grasping the bleeding vessel with a laparoscopic grasper and applying diathermy. More sophisticated energy devices such as LigaSure or Harmonic devices may also be used to divide the mesoappendix but are costly and generally unnecessary. Whichever strategy is planned, it is useful to ensure that the instrument required is readily available before starting to divide the mesentery. The appendix can be secured, by either endoloops or a clip, close to the base, prior to division and extraction of the specimen. A more costly, but equally effective, option is the use of an endostapler, which offers the advantage of stump closure and division in a single application. Burial of the appendicular stump is not usually performed during laparoscopic surgery and no significant sequelae have resulted from this approach.

Port-site contamination, as the inflamed appendix is withdrawn, should be minimised and a specimen retrieval bag, if available, should be used. This is particularly important when there is a distended, severely inflamed or gangrenous appendix specimen. The bag should be introduced and retrieved through a 10 mm port. It is strongly recommended to close all 10 mm ports with secure closure of the fascia to prevent port-site herniae. Port-site herniae are rare after 5 mm ports, such that closure is not required.

OPEN APPENDICECTOMY

If the preoperative diagnosis is fairly certain, the surgeon will probably choose a small right iliac fossa incision (see Chapter 6). Pus may be encountered on opening the peritoneum and is removed by suction. The first step is to deliver the caecum into the wound, and this can be difficult through the small incision. Small bowel loops lying anterior to the caecum are often repeatedly delivered to the surface. They can be differentiated from the caecum by the absence of taeniae coli. Occasionally, a long transverse colon is delivered in error, but it can be recognised by the attached greater omentum. The simplest method of isolating the caecum is to introduce an index finger lateral to all bowel loops, down into the paracolic gutter lateral to the caecum. It is then usually possible to hook the finger under a caecal taenia and to draw a portion of the caecum gently out of the wound. The taenia is then followed to its termination and the appendix delivered. If the appendix does not immediately deliver



13.5 Appendicectomy. (a) The appendicular vessels are ligated and the mesoappendix divided (the artery forceps on the appendicular vessels have been omitted for clarity). (b) The base of the appendix is ligated. If a seromuscular purse-string suture is used, it must be placed so that injury to vessels in the transected mesoappendix is avoided. (c) Artery forceps are applied to the appendix distal to the basal ligature and the appendix is divided. Any spillage will be onto the underlying swab. (d) Pressure with the artery forceps invaginates the appendix stump as the purse-string suture is tightened. ⏎

into the wound at this stage, a finger is reinserted into the wound along the taenia towards the caecal pole, where it is usually possible to feel the appendix as a tense cord, hook the finger around it and gently deliver it. If there is still difficulty, the wound must be enlarged for adequate access. The appendix may be wrapped in omentum, which can be gently freed or a portion of adherent omentum can be excised with the appendix. The appendix may be lying retroperitoneally in a retrocaecal position and can be delivered only after lateral caecal mobilisation has allowed the caecum to be rotated medially and the appendix dissected out under direct vision. A superolateral muscle-cutting wound extension will usually be required to give sufficient access for this manoeuvre.

Once safely delivered, the appendix is held in Babcock forceps while the mesentery is viewed against the light to identify the anatomy of the appendicular vessels. A window in the mesentery near the base of the appendix allows the application of artery forceps and division of the mesentery (Figure 13.5a). It is often advisable to divide the mesentery in separate bites if the artery has split into individual branches, and this may also be safer in a fat-laden or oedematous mesentery. The arteries held in the artery forceps are then ligated. It is important that these forceps do not slip during ligation or the mesentery, with the unsecured vessels, may retract inside the abdomen and be difficult to re-secure. Back-bleeding from the cut distal end is usually minimal but, if troublesome, can be controlled temporarily with artery forceps. Care must be taken not to injure the terminal ileum or its mesentery during dissection of inflamed tissue. It is also important to remove the *whole* of the appendix. If an overgenerous appendix stump is left *in situ*, a further attack of appendicitis, with a dangerous delay in diagnosis, is possible.

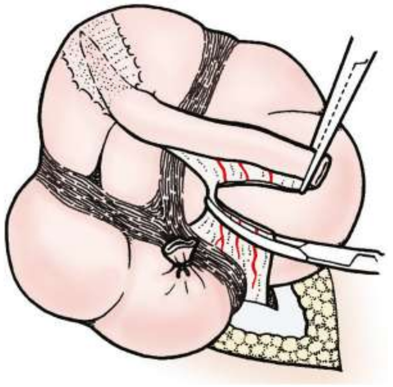
The appendix is now attached only by its base. This is ligated with an absorbable suture (Figure 13.5b). Traditionally, the appendix base was crushed with artery forceps prior to ligation. This was to reduce the swelling in the tissue to be ligated over a wider area than that compressed by the subsequent ligature, and thus reduce the likelihood of the ligature cutting through the oedematous tissue. Most surgeons no longer recommend this preliminary crushing manoeuvre, which theoretically can damage and devascularise the point of ligation. Artery forceps are placed 5 mm distal to the ligature. The appendix is then divided with a scalpel, cutting flush with the artery forceps (Figure 13.5c). The traditional purse-string suture has also lost popularity and is considered unnecessary by many. A purse-string suture is a seromuscular suture encircling the appendix stump and can be inserted after ligation of the mesoappendix, either before or after the appendix is removed. Care must be taken when inserting a purse-string suture not to catch the vessels in the base of the divided mesoappendix. As the purse-string suture is tightened and ligated, the stump is inverted by pressure with artery forceps (Figure 13.5d). The argument for an invaginating purse-string suture is the possible deleterious effect of infected stump mucosa left exposed to the peritoneal cavity. It is also an extra closure should the ligature on the base of the appendix fail. A counterargument by those not in favour of a purse-string suture is that there is no evidence that the infected mucosa is harmful, if left exposed, and that a purse-string suture may merely trap any infection to form an intramural caecal abscess. All, however, agree that any attempt to place a purse-string suture in thickened oedematous tissue is contraindicated, as it will fail to invert the stump and will only cause damage to the friable caecal wall.

Frequently, the base of the appendix is more accessible than the tip. If an inflamed retroperitoneal tip cannot be delivered into the wound, a retrograde appendicectomy is a useful manoeuvre (Figure 13.6). Two pairs of artery forceps are insinuated through the mesoappendix and applied to the base of the appendix, 5–6 mm apart. The proximal forceps are then removed and the appendix ligated in the groove that has been crushed. The appendix is then divided close to the distal forceps, which are left on for retraction as the appendix is freed by dissection, and by successive clamping and cutting of its mesentery.

SPECIAL CONSIDERATIONS IN APPENDICECTOMY

Generalised peritonitis

An acutely inflamed appendix that has ruptured freely into the peritoneal cavity causes a generalised peritonitis. This is common in children, as the ability to localise and wall off an intra-abdominal infection is less well developed, at least in part explained by the shorter omentum. In addition, in the preschool child, presentation of appendicitis is often atypical and the diagnosis delayed. Surgery is urgent but relevant preoperative resuscitation should not be overlooked. The appendix is commonly easily accessible and is removed in the standard manner. All pus should be aspirated from the peritoneal cavity, which is then further irrigated with saline or a bactericidal solution. A general peritoneal drain is of little value, but a wound drain should be considered in an open operation. A full therapeutic course of broad-spectrum antibiotics greatly reduces postoperative septic complications.



13.6 A retrograde appendicectomy is a useful technique when the base of the appendix can be drawn into the wound but the inflamed tip is difficult to deliver. ⏎

Localised appendix mass or abscess encountered at appendicectomy

An acute appendicitis may be walled off from the general peritoneal cavity by adherent omentum or small bowel. Alternatively, if the appendix is lying retrocaecally, the inflammation is localised by the overlying caecum. Pus may form within the mass and the resultant appendix abscess may thus be either intraperitoneal or retrocaecal (and mainly retroperitoneal), dependent on the position of the appendix. An inflammatory appendix mass is frequently palpable in the right iliac fossa preoperatively, but often only after the patient is anaesthetised and the abdominal wall relaxed. The presence of a mass is an indication that the operation may be more difficult and that more extensive access than usual may be necessary. Loops of small bowel involved in an appendicular inflammatory mass must be freed very gently, as the bowel will be friable. Omentum can be either separated from or excised with the appendix. When localised pus is encountered within the inflammatory mass and a drain has been placed into the depths of the abscess cavity after the appendix has been removed, this drain should be brought out through a separate incision.

Delayed presentation

If a patient presents with a history of several days' duration and an appendix mass without any signs of generalised peritonitis, conservative management with antibiotic therapy is often safer. Because of the perceived risk of a future attack, traditionally elective appendicectomy at 3–6 months has been recommended. The risk of a future attack of appendicitis was probably overstated historically, but there is a significant neoplasia rate in interval appendicectomy specimens, and many still recommend that it is considered for this reason.[8] In an older patient, it is advisable to exclude an inflammatory episode associated with a caecal or colonic carcinoma by colonoscopy after the acute inflammation has settled.

If a patient with a delayed presentation and an appendix mass fails to improve on antibiotics, a significant collection of pus within the inflammatory mass should be suspected. This abscess cavity requires drainage. Where the equipment and skills are available, ultrasound or computed tomography (CT) imaging can confirm a collection and, if confirmed, radiological image-controlled drainage is now an alternative for many patients with an abscess. After drainage, the acute episode should resolve on conservative management and an interval appendicectomy can be planned if considered appropriate. When this radiological service is not available, the diagnosis must be made on clinical criteria and open operative drainage may be needed. This may be safely combined with an appendicectomy in most situations. However, the surgeon may encounter an inflamed appendix densely adherent to loops of friable small bowel, which are also forming the wall of the abscess. Simple drainage of the localised abscess and antibiotic therapy are safer than attempting an appendicectomy in these circumstances. Injudicious attempts to mobilise the appendix at the initial operation may result in haemorrhage or small bowel injury with resultant fistulae.

Appendicitis in pregnancy

Surgery is often delayed in pregnancy for fear of an unnecessary laparotomy inducing a miscarriage or premature labour. However, it is the intra-abdominal inflammatory process itself, rather than the surgery, whether open or laparoscopic, that will most frequently precipitate uterine contractions. Early surgical intervention is therefore indicated. In late pregnancy, the caecum and appendix will be displaced upwards by the gravid uterus, and this can cause diagnostic confusion. It should also be remembered that, in late pregnancy, an incision for open appendicectomy will need to be made higher on the abdominal wall. When approaching the surgery laparoscopically, alternative port sites are required to account for the gravid uterus.

Avoidance of postoperative septic complications

Before the advent of antibiotics, wound infections and pelvic abscesses were common after appendicectomy. Great care was taken to change instruments and gloves after contact with mucosa, which was itself then inverted with a purse-string suture. However, contamination of the pelvic peritoneum had already occurred preoperatively and the wound was inevitably contaminated as the appendix was delivered. It is now standard practice to administer prophylactic, perioperative antibiotics for all appendicular and colonic surgery, even in the absence of an infective pathology, and when a grossly inflamed or perforated appendix is found, a postoperative treatment regime of antibiotics is instigated. As a result of this change in practice, infective complications following appendicectomy are now comparatively rare.

PERIOPERATIVE DIAGNOSTIC DILEMMAS

Pelvic peritonitis from another pathology, such as diverticulitis or salpingitis, will often have an appendix lying within the pus and such an appendix will show serosal inflammation. Awareness of this possibility is usually sufficient to prevent a misdiagnosis. If there is some anxiety after the removal of a relatively mildly inflamed appendix associated with pelvic pus, a useful test is to open the appendix. A pale, non-inflamed mucosa confirms the suspicion that the appendix is inflamed from without by another pathology, which must then be sought. When a small right iliac fossa incision has been utilised at open approach, extension of the wound or a separate midline laparotomy incision is often necessary for this exploration.

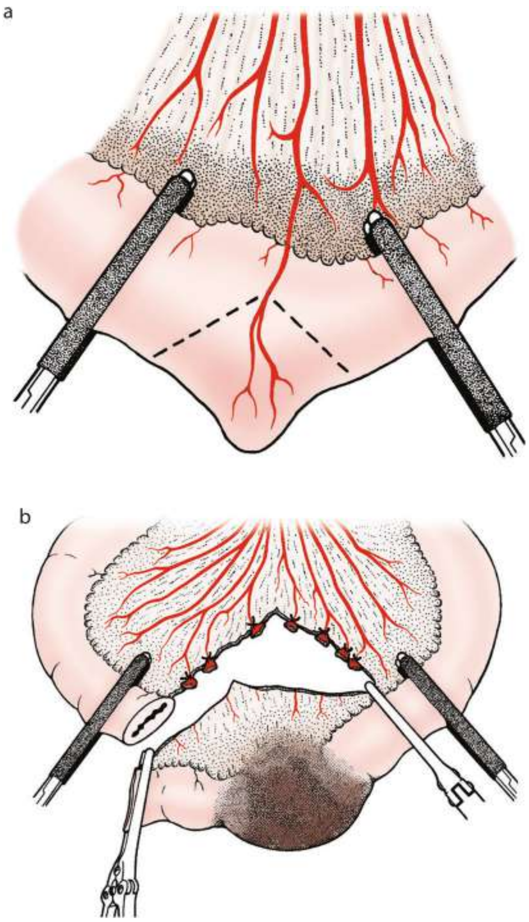
During an open appendicectomy, an entirely normal appendix may be encountered; however, it should be removed to prevent future diagnostic difficulties in a patient with a scar typical of prior appendicectomy. In the absence of peritonitis, the original incision is adequate for a limited laparotomy and ileal loops should be delivered; mesenteric adenitis, a Meckel's diverticulum or terminal ileal Crohn's disease may also be apparent. The right ovary and Fallopian tube are also accessible for examination. The finding of a normal-looking appendix at laparoscopy is less problematic in this context, as laparoscopic abdominal assessment is easy to perform.

Occasionally, an unexpected finding of a caecal carcinoma is made and a radical right hemicolectomy should be undertaken. An inflammatory mass in the right iliac fossa, from an inflamed or perforated caecal diverticulum, also requires a right hemicolectomy, which should be a radical dissection if a carcinoma cannot be excluded.

An *appendicular tumour* is occasionally encountered, and may coexist with an acute appendicitis, distal to where the tumour has obstructed the lumen. The most common of these is a carcinoid and, if a tumour is less than 2 cm in diameter and well clear of the base, a simple appendicectomy is still appropriate. Larger or more proximal tumours require a formal right hemicolectomy, as malignant carcinoids and adenocarcinoma can both arise in the appendix. A true mucocoele of the appendix is occasionally encountered and represents a non-inflamed, obstructed appendix filled with mucus. A mucinous cystadenoma of the appendix is a separate entity. It must not be ruptured during the appendicectomy, as rupture may result in peritoneal contamination with subsequent pseudomyxoma peritonei (see Chapter 14). If the tumour has already ruptured, or ruptures during surgery, follow-up should be arranged at a specialised centre, as early surgical treatment of the disseminated intraperitoneal pseudomyxoma will be more successful than treatment delayed until there is clinical evidence of the established syndrome.

SMALL BOWEL RESECTION

A small bowel resection may be indicated if either the mesentery is diseased or injured, leading to ischaemia of the bowel segment, or there is direct involvement of the bowel wall in an inflammatory or malignant process. The radicality of a resection must be tailored to the pathology. For example, if only the antimesenteric border of the small bowel is involved by a benign pathology, a limited V-shaped wedge resection will suffice (Figure 13.7a). The advantages of this include an intact strip of bowel at the mesenteric border, with no ligation of mesenteric vessels required, and the angulation after closure of the defect protects the suture line from forming adhesions with other peritoneal surfaces. This form of resection may be suitable for a strangulated Richter's hernia or excision of a Meckel's diverticulum, although an incidental finding of a Meckel's diverticulum is now considered best left alone. A wedge resection may also be suitable for the palliative excision of a malignant peritoneal deposit on the small bowel causing narrowing of the lumen.



13.7 (a) A limited V resection, which leaves the mesenteric border intact, is sometimes appropriate. (b) More often, a full circumferential resection is needed, requiring excision of a V of mesentery. ⏎

More frequently, the whole circumference of the small bowel must be excised (segmental resection) and, even when this is only a few centimetres in length, a V of mesentery must also be removed (Figure 13.7b). Division of the mesentery is most simply carried out through clamping with a succession of artery forceps and cutting with scissors. The vascular pattern of the mesentery can be displayed by means of transillumination with a bright light. Windows can then be made through the avascular areas, between the vessels, and the artery forceps applied to the tissue between the windows. The tissue held in the forceps is then ligated. The temptation to include a large bulk of mesentery in each clip should be resisted, as this nearly always results in tearing and bleeding as the ligature is tightened. When a curable malignancy of the small bowel is suspected, the V of mesentery that is removed should give the maximum lymphadenectomy without damage to the main branches of the superior mesenteric vessel. The technical details of a bowel resection and an end-to-end anastomosis are described in more detail in Chapter 7.

SURGERY FOR INTESTINAL OBSTRUCTION

The initial management of any patient with an intestinal obstruction is correction of the fluid and electrolyte deficit by intravenous fluids, combined if possible with deflation of the bowel (see Chapter 7). A nasogastric tube is passed and the contents of the distended stomach are aspirated. The nasogastric tube is then attached to a bag and left on free drainage, in addition to intermittent aspiration. The small bowel becomes progressively deflated as the obstructed intraluminal contents reflux back into the stomach and are aspirated. A patient with a distal large bowel obstruction may benefit from nasogastric aspiration if there is additional distension of the small bowel, particularly if there is an incompetent ileocaecal valve, but otherwise nasogastric decompression is of little value.

The next phase in the management is clinical and radiological assessment of the patient and the decision as to whether emergency surgery is indicated. This decision hinges on the likelihood of an ischaemic or strangulated segment of bowel.

A firm diagnosis of the underlying pathology may be possible at this stage, but more often the surgeon continues with conservative treatment or plans an emergency operation with only a tentative diagnosis. Preoperative imaging, however, should at least have helped to differentiate between small and large bowel obstruction. Plain abdominal X-rays are helpful but CT scanning, if available, is now the investigation of choice in the assessment of a patient with bowel obstruction. Small and large bowel obstruction are discussed separately, as the issues differ.

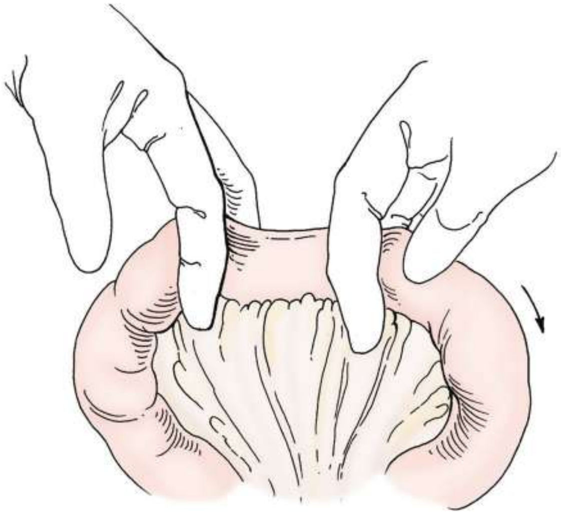
SURGICAL CONSIDERATIONS IN PATIENTS WITH SMALL BOWEL OBSTRUCTION

General anaesthesia must be combined with precise protection of the airway from inhalation of vomit. Either laparoscopic or open surgery may be suitable. Significant small bowel distension will make laparoscopy more difficult, and an early decision to convert to open surgery may be prudent, especially if widespread adhesions are encountered. Conversion is also considered when a resection is warranted or in the presence of a perforation.

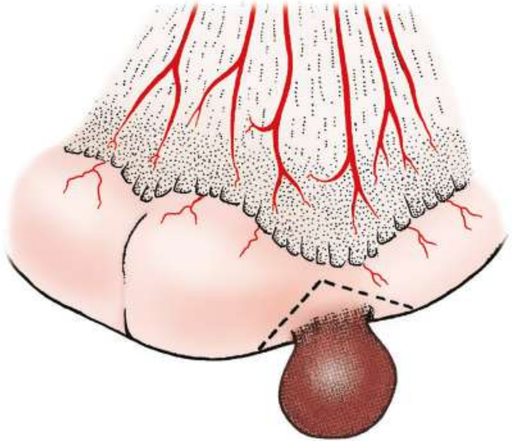
On entering the abdomen, the cause of the obstruction may be immediately obvious, but, more often, nothing can be seen initially except distended loops of small bowel, which should be displaced to the left so that the caecum can be inspected. A *collapsed caecum* confirms the presence of a small bowel obstruction, as the *caecum is distended* when the obstruction is due to large bowel pathology. The right iliac fossa and pelvis are explored, seeking a collapsed loop of small bowel. (If there is a *collapsed caecum but no collapsed distal ileum*, the obstruction is very close to the ileocaecal valve and is almost certainly a carcinoma of the caecum.) Unfortunately, this is frequently found to be the cause of a small bowel obstruction in an older patient. When collapsed ileum is identified, it is traced proximally until the obstruction is encountered. If a single adhesion, it can simply be released, but often both the collapsed and the dilated loops are bound by multiple adhesions, which must also be dissected free. This can be a tedious process, especially if loops of distended bowel are adherent in the pelvis. Extreme gentleness is essential, as tears in obstructed, tethered small bowel loops deep in the pelvis make further mobilisation increasingly difficult, especially as an inadvertent enterotomy often cannot be repaired, or even fully controlled, until the loop is freed. Distended loops of bowel should, if possible, be retained within the abdomen but, if this is not possible, they should be covered with a warm moist pack and supported outside the wound to prevent undue traction on the mesentery.

If a loop of strangulated bowel is encountered, a decision on viability must be made. Grey or black bowel with a lustreless, flaccid sodden wall is obviously non-viable and must be resected. More often, the viability of the strangulated loop is uncertain and perfusion must first be restored. The decision may then be easy if there is either a rapid recovery or no improvement, but if there is still doubt, the loop should be left undisturbed within the peritoneal cavity for 5–10 minutes before reinspection. On occasion, the loop is viable except for narrow non-viable bands at the site of the constriction; these can be safely invaginated with seromuscular sutures.

Even if the obstruction has required only a simple release, closure of the abdomen after a laparotomy may be difficult until further small bowel deflation has been achieved. This can be done by 'milking' back the small bowel contents into the stomach, from where bowel contents can be aspirated through the nasogastric tube by the anaesthetist (Figure 13.8). Alternatively, a needle aspiration (see Chapter 13) may be a useful manoeuvre. In the presence of perforation, the bowel is often oedematous, and closure would lead to raised intra-abdominal pressure; a laparostomy can be a prudent option here, but comes with its own risks. Surgery may demonstrate a small bowel



13.8 Gastrointestinal contents can be 'milked' from a dilated segment of the bowel into a segment from which they can be removed. ⏎



13.9 A Richter's hernia. Only part of the circumference of the bowel is trapped, and strangulation can occur without obstruction. ⏎

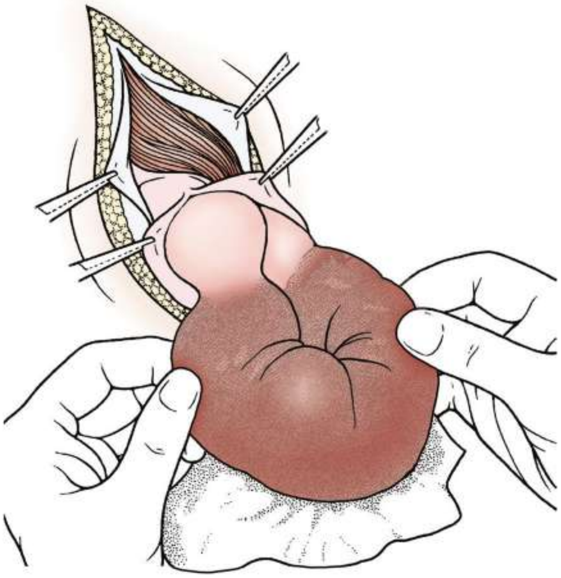
obstruction secondary to some underlying pathology that needs to be addressed in its own right.

CAUSES OF SMALL BOWEL OBSTRUCTION

External herniae

An *irreducible* external hernia must be sought in any patient with small bowel obstruction. A reducible hernia is an incidental finding and not the cause of the obstruction. All hernial orifices must be checked, remembering that an irreducible femoral hernia is easily overlooked in an obese patient. A *strangulated* hernia is one in which the contents are constricted in such a way that the blood supply is impaired. An irreducible hernia, causing a small bowel obstruction and often labelled an incarcerated hernia, will usually progress to a strangulated hernia with a strangulated loop of small bowel, and emergency surgery is indicated. A strangulated hernia, in the absence of obstruction, generally contains omentum, but a *Richter's hernia* (Figure 13.9), in which only part of the circumference of the gut is trapped and the lumen is still patent, is a possibility. The colon, in contrast with the small bowel, is seldom obstructed or strangulated within a hernia.

The hernia may be a primary groin, epigastric or para-umbilical hernia, or it may be an incisional or parastomal hernia. The surgical approach and initial dissection are similar to those in an elective hernia repair (see Chapters 6 and 16). The hernial sac is then opened. Blood-stained fluid confirms strangulation of the contents and foul-smelling fluid suggests non-viable bowel. Contamination of the wound by this fluid should be minimised, as it will be heavily colonised with faecal organisms. The strangulating constriction must then be released in order to restore perfusion to the compromised contents (Figure 13.10). In an *indirect inguinal hernia*, the constriction is usually the tight peritoneal neck of the sac while, in an *incisional hernia*, it is more often the edge of the fascial defect, both of which are easily released. The strangulation in a *para-umbilical hernia* is frequently at the narrow neck of a loculus of the sac. A *femoral hernia* is constricted by the femoral ring itself; release is difficult and access is poor from below. A minor release is possible by a medial incision into the lacunar ligament, but occasionally troublesome bleeding from an aberrant vessel is encountered. If release is inadequate, and



13.10 A strangulated loop of small bowel in an inguinal hernia has been released by a peritoneal incision in the neck of the sac. ⏎

especially if there is any concern over the viability of the bowel in the sac, access from above is also necessary. If a low approach to the hernia has been made, an additional abdominal incision is usually required: either a midline incision or a low iliac fossa incision (see Chapter 6). If the bowel still cannot be delivered out of the hernial sac, it may be necessary to divide the inguinal ligament close to the pubic tubercle and reattach it at the end of the operation.

If, on release of the constriction, the hernial contents quickly regain perfusion, a simple return of the contents to the peritoneal cavity and repair of the hernia are all that is required. The decision to resect is straightforward if no improvement occurs on releasing the constriction. If the surgeon is faced with doubtfully viable bowel and the abdomen is not open, it is unwise to replace the loop to aid recovery, as it may be difficult to retrieve this loop again. Instead, it should be covered with a warm moist towel and left undisturbed for 5–10 minutes.

Occasionally, a strangulated hernia reduces spontaneously, early in an operation, before the sac is opened. If, on opening the sac, blood-stained fluid is encountered, the surgeon must locate the bowel loop, or omentum, that had been trapped in order to check the viability of the strangulated tissue. A congested small bowel loop may be retrieved via the hernial neck and drawn back into the operative field for inspection, but laparoscopy or a small laparotomy incision is often required in this situation. In a ventral hernia, an extension to the wound is usually all that is required, but, if operating on a groin hernia, a separate incision may be necessary.

Infarcted omentum can be simply excised with a transfixion ligation just proximal to the termination of the viable tissue. A resection is mandatory for non-viable bowel and may be difficult because of limited access. In an adult patient with a strangulated inguinal hernia, a resection may be performed without opening the general peritoneal cavity. After completion of the anastomosis, the bowel is replaced within the abdomen and the peritoneum at the neck of the sac is closed. If there is difficulty replacing the bulkier anastomosis through the deep ring, a lateral release of the ring may be necessary. This is a particular problem on the rare occasions when a bowel resection is necessary in a strangulated infantile inguinal hernia. A similar difficulty occurs after a resection for a strangulated femoral hernia operated on through a low incision. This scenario should be anticipated, and avoided, by employing an additional separate abdominal incision for the resection and the anastomosis.

A non-viable loop of colon is fortunately relatively rare in a strangulated hernia, but if encountered will require a large bowel resection of obstructed colon, as discussed later in this chapter. A laparotomy incision is mandatory for adequate access.

A problematic decision in emergency groin hernia surgery is whether a mesh can be used to repair the defect. If the bowel is healthy after reduction of the hernia, a mesh may be used with antibiotic prophylaxis. If a bowel resection is required, a mesh may still be used, taking care to complete the surgery without contamination. If the bowel was perforated or an abscess was present within the hernial sac, then a mesh repair is contraindicated.[9]

Adhesive bowel obstruction

The most common cause of small bowel obstruction is an adhesive obstruction with a loop of small bowel compressed, kinked or twisted by an adhesion following previous surgery. Any patient with an abdominal scar or a history of a vaginal hysterectomy, presenting with obstruction, can be presumed to have an adhesive obstruction of the small bowel in the first instance, provided that a strangulated external hernia has been excluded. Deflation with a nasogastric tube may be sufficient to allow the situation to resolve, with surgery not required.

Closed-loop adhesive obstruction is a variant of the common small bowel obstruction. It may be a closed loop from the start if a small bowel loop has twisted around a band. Alternatively, the episode may start as a simple obstruction, but subsequent dilatation and displacement of bowel loops can cause a second, more proximal, obstruction. Once a closed-loop obstruction has occurred, it cannot be decompressed from above by nasogastric aspiration. Distension increases and the bowel becomes ischaemic from excessive intramural pressure, even in the absence of a significant twist in the mesentery. However, the distended loop often rotates, with resultant occlusion of the mesenteric vessels, which then becomes the most important factor in the ischaemia of strangulation.

An ischaemic loop causes continuous abdominal pain in addition to the colic of obstruction. A careful history may elicit this symptom, and abdominal examination should demonstrate peritoneal irritation. However, it should be remembered that, in full-thickness inflammatory small bowel conditions causing obstruction (e.g. Crohn's disease), peritoneal inflammation does not necessarily indicate ischaemia, and continuing conservative management, despite local peritonism, may be appropriate. A rising pulse rate and a leucocytosis are markers of the systemic inflammatory response to an ischaemic loop of bowel and are useful monitoring parameters during the conservative management of a small bowel obstruction. A metabolic acidosis and rising serum lactate are also predictive of ischaemia and can be useful adjuncts in determining the safety of expectant management. Urgent surgery is indicated whenever strangulation is suspected.

In a simple obstruction, with no indication of strangulation, conservative management may be continued for 72 hours but, if resolution has not occurred, surgery should be planned. A water-soluble small bowel contrast study may be valuable in distinguishing a patient with an obstruction that will resolve from a patient in whom surgery will be required. For example, Urografin® (40 mL in 40 mL of water) can be administered orally or via a nasogastric tube and the patient X-rayed 4 hourly to detect contrast medium reaching the caecum. A water-soluble study may provide an answer without the need for X-rays, as the patient either passes flatus and diarrhoea or becomes more distended and experiences increased pain. Laparoscopic adhesiolysis may be attempted if the bowel distension is significantly reduced after conservative management and where prior abdominal disease (e.g. peritonitis) or surgical intervention has not been too extensive. Laparoscopic adhesiolysis offers the advantage of reduced subsequent adhesion formation in addition to faster recovery and other benefits in postoperative recovery.[10]

A small bowel obstruction with no previous surgery is unlikely to be due to adhesions. Congenital adhesions, inflammatory adhesions from previous diverticulitis or gynaecological pelvic inflammatory disease, and adhesions from blunt abdominal trauma remain a possibility, but an alternative intra-abdominal pathology, especially malignancy, is increasingly likely. In the absence of symptoms or signs of strangulation, emergency surgery is not necessary and initial treatment can be conservative. Intravenous fluid resuscitation and nasogastric decompression improves the well-being of the patient, and cross-sectional imaging by CT scanning may help in diagnosing the cause. However, surgical intervention is usually required and should not be unnecessarily delayed.

A postoperative small bowel obstruction can be difficult to differentiate from an ileus and, in patients who have had a laparoscopic operation, surgeons must be alert to the possibility of small bowel trapped in a port-site hernia. A mixed picture of small bowel obstruction and ileus is also sometimes encountered postoperatively. This was common after appendicectomy before antibiotics were used routinely, and often occurred after an initial return of bowel function. It is usually associated with intra-abdominal inflammation or abscess formation. If there is a significant collection of pus, drainage is required, but otherwise treatment should be conservative. The loops of oedematous small bowel involved in the inflammatory process will recover with rest and antibiotics. Intravenous nutrition is often indicated if recovery is prolonged. Surgery should ideally be avoided, as it carries a considerable risk of damage to friable bowel.

Intraluminal obstruction

An impacted ingested foreign body or a gallstone can be removed by simple enterotomy. In *gallstone ileus*, this is adequate definitive treatment. The fistula between the biliary tract and the small intestine is serving a similar purpose to a therapeutic sphincterotomy and, as an associated cholecystectomy may be difficult and potentially dangerous, only an experienced biliary tract surgeon should consider proceeding further.

Ascaris lumbricoides infestation can produce an obstruction from a bolus of worms. Management of the obstruction is conservative, and deworming should be postponed until the obstruction has resolved. If a laparotomy has been performed, an enterotomy is normally avoided for fear of migration of worms through the suture line; fortunately, it is usually possible to ‘milk’ the worm bolus through into the caecum.

Benign strictures

The operative decision-making around the management of patients with benign strictures depends on the aetiology. Fibrous strictures can be treated by stricturoplasty or a limited bowel resection. Strictures associated with Crohn’s disease or tuberculosis are discussed later in this chapter. A radiotherapy stricture secondary to chronic radiation enteritis, causing obstruction, requires a resection that includes the adjacent bowel, which has inevitably also been damaged by the radiotherapy. In this context, an ileocolic anastomosis is safer than an ileum-to-ileum anastomosis, as the colon is often uninvolved by radiation.[11]

Internal herniae

An internal hernia may involve only a partial circumference knuckle, or a short segment of small bowel, trapped beneath a peritoneal fold or within an obturator defect. The bowel is released and resected if non-viable and the space where the bowel was trapped is obliterated or repaired. However, the herniation may represent a more serious form of the closed-loop obstruction discussed above. The greater part of the small bowel may have herniated through a mesenteric defect, the anatomy is difficult to elucidate, and release of the constriction must be cautious or mesenteric vessels at the edge of the defect will be damaged.

Strangulated stomach within a hiatus hernia and strangulated colon through an old diaphragmatic laceration are further potentially serious forms of internal herniation. Patients with a Roux-en-Y gastric bypass, after either bariatric surgery or surgery for upper gastrointestinal cancer, have a predisposition to internal hernia through the defect created by the Roux limb.

Small bowel volvulus

A small bowel volvulus may endanger the perfusion of the whole small bowel. Those that occur in infancy are commonly associated with congenital intestinal malrotation or occur around a vitello-intestinal duct remnant attached to the abdominal wall. Adult small bowel volvulus is a common condition in some parts of the world, where it is sometimes encountered around the base of a sigmoid volvulus to produce a complicated 'ileosigmoid knot'.[12] The operation consists of release of the constriction by de-rotation, first of the loops of small bowel and then of the large bowel. Any non-viable portions are resected.

Intussusception

The apex of an intussusception usually lies in the ascending or transverse colon and consists of an area of abnormal ileum. Operative reduction of an intussusception is by repetitive gentle squeezing of the bowel, just distal to the apex, which moves progressively more proximal as the intussusception is reduced. Reduction by traction is liable to cause damage. If reduction is not possible, a resection is necessary, most often in the form of a right hemicolectomy. After a successful reduction, a resection may still be necessary if the bowel is infarcted or if it has torn during reduction. In addition, in adult patients, the apex is commonly a small bowel tumour, which requires a resection with inclusion of its lymphatic drainage. The common infantile intussusception can usually be managed non-operatively (see Chapter 27).

Small bowel tumours

The surgery of these relatively uncommon tumours is resection with a generous 'V' of mesentery in order to obtain a radical lymphadenectomy. The tumour may be an adenocarcinoma, a carcinoid or a lymphoma. It is important to check the whole small bowel carefully for additional tumours, as carcinoids are frequently multiple (see Chapter 14).

Malignant adhesions and peritoneal deposits

A patient presenting with a small bowel obstruction may have a loop of small bowel adherent to a previously undiagnosed intra-abdominal malignancy. If the primary tumour is resectable, the only chance of cure, and usually the best palliation, is achieved by a radical resection of the primary tumour *en bloc* with the involved loop of small bowel.

A patient with multiple peritoneal malignant deposits may present with a small bowel obstruction. One side-to-side anastomosis (or more) may relieve the obstruction, but often little can be achieved by surgery (see Chapter 14).

LARGE BOWEL OBSTRUCTION

Large bowel obstructions can result from a colorectal malignancy, inflammatory conditions, volvulus, herniae or bezoars. Large bowel adhesive obstruction is rare and, for this reason, most large bowel obstructions require surgical management. Large bowel obstruction can present with perforation at the site of the lesion or in the proximal colon (often a caecal perforation). In the case of a pseudo-obstruction (Ogilvie syndrome), there is no mechanical obstruction, but various factors combine to cause an atonic and dilated colon, which may respond to conservative measures.

SURGICAL CONSIDERATIONS FOR LARGE BOWEL OBSTRUCTION

Many large bowel obstructions pose no immediate threat to bowel wall viability. Urgent, rather than emergency, surgery is therefore indicated, and a delay of 24–48 hours for resuscitation and further assessment can be beneficial. The rectum must be checked digitally, and by sigmoidoscopy, for an obstructing rectal cancer and also for any synchronous pathology. Whether an open or a laparoscopic operation is chosen will depend on the surgeon's preference, experience and available resources, in addition to the level of the obstruction, the likely pathology and the degree of bowel distension. If the obstruction is left sided, the patient should be positioned with 'legs up' to afford access to the anal canal. The rectum must be assessed in theatre by digital and rigid or flexible sigmoidoscopic examination, if this has not already been done, as, even if the obstruction is known to be more proximal, a small synchronous lesion in the rectum must be excluded. Additionally, a rectal obstruction can be mistaken at operation for a pseudo-obstruction. It is therefore essential to ensure that any distal bowel, where access for inspection and palpation is difficult from above, has been fully examined from below.

If the ileocaecal valve is patent, there may be gross small bowel distension in addition to large bowel distension. Even in an open operation, through a generous midline incision, deflation may be necessary before further exploration is possible. A sucker can be introduced into both the ileum and the caecum through a small incision in the distal ileum, controlled by a purse-string suture. This can be very helpful in reducing gaseous distension; however, in the colon, the sucker tends to block quickly with semi-solid faecal matter, and it is easy to cause gross peritoneal faecal contamination during this manoeuvre. The operative strategy in a large bowel obstruction then depends on the underlying pathology and the site of the obstruction.

Malignant large bowel obstruction

Malignancy is the most common cause of a large bowel obstruction in the Western world. Many of these tumours are still potentially curable, and a major radical resection, as described in Chapter 14, is required. Endoluminal endoscopic stents, if available, may be considered preoperatively for left-sided lesions but, when an irresectable tumour is found at surgery, a proximal loop stoma may be the only practical solution. However, a bypass should also be considered, as it avoids the distress of a stoma (see Figures 14.5 and 14.11).

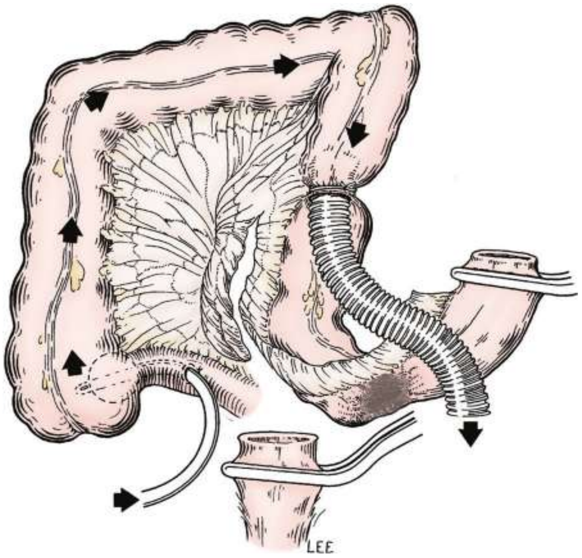
Right colonic obstruction Right colon tumours are treated by a standard radical right hemicolectomy. The presence of obstruction is seldom a major problem during mobilisation of the right colon and the small bowel is deflated by intraluminal suction through the divided ileum, prior to the anastomosis. The more distal colon is relatively empty and an ileocolic anastomosis is generally safe in the management of an obstructed right colon. An obstructed transverse colon cancer is best treated by an extended right hemicolectomy so that the ileum is anastomosed to the descending colon. In an attempt to use ileum as a safer anastomosis, this concept has been extended into a subtotal colectomy and ileorectal anastomosis for many patients with an obstructing carcinoma of the descending colon or sigmoid. If this resection is chosen, the surgeon must keep in mind the segment of colon that requires the radical lymphadenectomy (see Figure 13.2). A subtotal colectomy and ileosigmoid or ileorectal anastomosis is particularly useful if the viability of the distended caecum is in any doubt. However, if the caecum is healthy, a safer anastomosis has been created at the expense of the loss of a large proportion of healthy colon, and some patients will be left with long-standing troublesome diarrhoea.

Left colonic resections Left colonic resections have a high morbidity when surgery is undertaken for colonic obstruction. The mobilisation of the colon can be technically challenging due to the obstructed, dilated bowel. In addition, a primary colonic anastomosis has high risk due to alterations in the colonic wall secondary to distension with tissue oedema and suboptimal arterial perfusion and venous drainage. Local infection or faecal peritonitis will further increase the anastomotic vulnerability, as does the poor general state of an ill or older patient.

Previously, a defunctioning right transverse colostomy was recommended to relieve a left colonic obstruction, with definitive surgery undertaken at a later date. A primary resection is now considered preferable, but should not be performed by an inexperienced surgeon or in suboptimal conditions, particularly outside normal working hours. Fortunately, most surgery for malignant large bowel obstruction can be safely delayed for 24–48 hours to allow optimisation of the patient's physiology and so that it can be performed under more ideal circumstances. If intervention has proved unavoidable in difficult circumstances, there may still be a role for a defunctioning colostomy. For example, a tumour of the splenic flexure can be technically difficult to mobilise if the colon is grossly distended. In this instance, it may be best to bring out a defunctioning stoma and delay the resection so that it can be carried out under elective conditions by a surgeon with more colorectal experience. An advanced obstructed tumour of the upper rectum (as discussed later) should often not be excised as an emergency procedure, even by an experienced colorectal surgeon. A proximal loop colostomy, followed by full assessment and preoperative radiotherapy prior to definitive resection, may improve the oncological outcome in some patients.

However, in most situations it is possible to perform an oncologically sound radical resection of an obstructed left colon tumour at the initial operation and, if feasible, this is the optimal management. If the tumour is resected as an extended right hemicolectomy, or a subtotal colectomy, a low-risk ileocolic or ileorectal anastomosis can be performed. However, if a standard radical left hemicolectomy has been performed, the choice is between a Hartmann's procedure and a high-risk anastomosis. The advantages of a shorter operation time and a lower risk with a Hartmann's procedure are offset by the necessity of a further major operation to rejoin the bowel if the patient is unhappy with a permanent stoma and reversal is to be performed at a future date.

When a reconstruction is planned after a left colonic resection for obstruction, the surgeon should consider the potential benefit of emptying the proximal colon prior to an anastomosis and of protecting the anastomosis with a proximal defunctioning loop stoma. Closure of a defunctioning stoma a minimum of 6 weeks later is a smaller procedure than the operation to reverse a Hartmann's procedure.



13.11 An on-table colonic washout. ⏎

On-table large bowel lavage This is the most satisfactory method of emptying the obstructed colon of faeces.[13] A catheter is inserted into the ileum through a purse-string suture and advanced through the ileocaecal valve into the caecum. Alternatively, the appendix is removed and the catheter is inserted into the appendix stump and a purse-string applied. The appendix stump is ligated when the irrigation is completed. The colon is divided above the obstruction and the end of the bowel is either placed outside the abdomen directly into a bowl or connected to a length of tubing (as shown in Figure 13.11) if there is insufficient length. Irrigation fluid is then run through the catheter until the bowel is empty of faecal material.

Diverticular obstruction

When the diagnosis of diverticular disease is certain at operation, the narrow area of bowel is excised by a sigmoid colectomy and there is no need for a radical lymphadenectomy. However, a surgeon often has to operate for a sigmoid obstruction of uncertain aetiology, and the resection should follow the steps for a radical resection if cancer cannot be excluded. Following the resection, the choice is again between a Hartmann’s procedure and the re-establishment of colonic continuity.

Volvulus

Sigmoid volvulus A sigmoid volvulus is the most common cause of large bowel obstruction in parts of Africa and Asia, where it occurs in all age groups. In Europe and North America, a sigmoid volvulus is generally a condition of older people. Diagnosis of sigmoid volvulus and the less common caecal volvulus is made on classical X-ray appearance, on plain abdominal imaging or, more accurately, on CT imaging, if available. A large bowel volvulus requires urgent release and, if the sigmoid is involved, this can usually be achieved endoscopically. Recurrence is a problem, but major emergency surgery in an older patient has been avoided. An endoscopic two-point fixation of the sigmoid loop using a percutaneous endoscopic gastrostomy (PEG) device is a compromise that may be worth considering in older people.

If a sigmoid volvulus cannot be decompressed endoscopically, or if there is concern over sigmoid viability, then laparotomy is needed. A viable sigmoid may be untwisted, but recurrence is likely. Attempts to fix the sigmoid to prevent recurrence are not always successful, nor are the ingenious attempts to plicate, or widen, the sigmoid mesentery.

However, the surgeon faced with a frail older patient wishes to avoid not only the risks of resection but also the danger of recurrent volvulus and the need for later elective surgery. It may then seem reasonable to attempt de-rotation and fixation. By contrast, in a fit patient, a sigmoid resection is the preferable option. A resection is also mandatory if the sigmoid has infarcted. Control of the vascular pedicle, before untwisting, will reduce the venous drainage of toxins into the circulation but may not be technically possible. A sigmoid colectomy is performed with preservation of the superior rectal artery. The surgeon then has three choices:

1. A primary anastomosis, with or without on-table lavage, can be performed, with the option of a proximal loop stoma. A primary anastomosis without a proximal temporary stoma is usually safe in young and otherwise fit patients.
2. The proximal end can be brought out as an end colostomy and the distal end can be brought to the surface as a mucous fistula. If they are adjacent, re-anastomosis at a later date is feasible as a relatively minor operation. However, there is seldom sufficient length in the distal limb to achieve this.
3. The distal end can be closed and an end colostomy formed as a Hartmann’s procedure. A second major operation will be required if the patient wishes bowel continuity to be restored.

Caecal volvulus A caecal volvulus is best treated with a right hemicolectomy, even if the bowel is viable, as attempts at caecopexy seldom prevent a recurrence. If fixation is to be attempted, the caecum can be sutured to parietal tissue or it can be tethered by a caecostomy. Endoscopic reduction should not be attempted because of low success rates and increased risks of complications.

Pseudo-obstruction

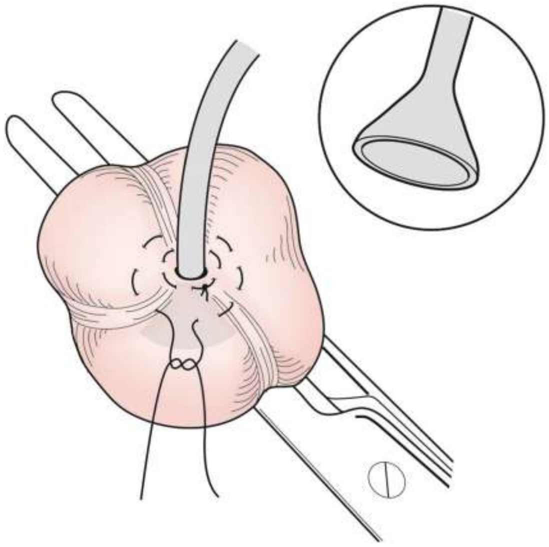
Pseudo-obstruction is difficult to differentiate from a distal large bowel obstruction, and a diagnosis should not be made without a confirmatory distal contrast study to exclude a mechanical cause. Pseudo-obstruction occurs classically in those who are ill and older people and is particularly common in orthopaedic inpatients who have had recent hip surgery. There is an overlap with sigmoid volvulus, and some patients have a history of both conditions. It is thought that the colonic distension of a pseudo-obstruction may predispose to a volvulus.

Treatment Surgery can usually be avoided by endoscopic deflation. Alternatively, neostigmine (2.5 mg dissolved in 50 mL of saline) can be given intravenously over 3–5 minutes. If ineffective, the treatment can be repeated after 20 minutes. A dramatic response is common, but the cardiovascular effects of this treatment must not be underestimated and full resuscitation facilities should be available. If medical management is ineffective, or contraindicated, then the next best option is endoscopic colonic decompression. This may often have to be repeated, and placement of a colonic drainage tube may also be necessary.[14] Failure of these methods, or progressive caecal distension that jeopardises viability, will necessitate surgery. More often, the abdomen has been opened on a preoperative diagnosis of a mechanical obstruction. The surgical options depend on the viability of the caecum and the probable precipitating causes of the pseudo-obstruction.

If the caecum is gangrenous, a right hemicolectomy with an ileocolic anastomosis is a possibility, but the back-pressure on the anastomosis is worrying if the pseudo-obstruction persists. The alternative, namely a right hemicolectomy with a terminal ileostomy, is safer, especially if the caecum has already ruptured. However, distension of the distal bowel may recur. This makes closure of the distal colonic end hazardous and is best brought out as a mucous fistula (see Chapter 14). If the caecum is viable at laparotomy, a tube caecostomy is a useful temporary solution in patients who have a background of normal bowel function and an obvious precipitative cause of the episode of pseudo-obstruction. In patients with long-standing problems of bowel motility, a caecostomy should be avoided, as it merely adds another complication to the already difficult long-term patient management.

Caecostomy

A caecostomy does not provide adequate drainage of an obstructed colon, nor does it afford useful or reliable protection of an anastomosis.[15] However, it can be a temporary life-saving method of colonic deflation in a patient with threatened caecal rupture whose general state precludes any immediate, more major, intervention.



13.12 A soft clamp prevents contamination until the catheter is firmly secured. The most suitable catheter is a de Pezzer with the end cut off, as shown in the inset. ⏎

An appendicectomy incision is made under local or general anaesthesia. The distended caecum presents on opening the peritoneum. The gaseous distension is relieved by needle puncture through an anterior taenia. This portion of caecum can then be drawn out of the wound, and a purse-string suture inserted through which a self-retaining catheter is passed into the caecum (Figure 13.12). The purse-string suture is tied and the catheter is brought out through a separate stab incision and secured with a skin suture to hold the caecum firmly against the anterior abdominal wall.

Postoperatively, a caecostomy tends to block with faecal matter and must be flushed regularly if it is to be of any benefit. Hourly flushing with 50 mL of saline is recommended in the acute situation. After 2 weeks, the tube can be removed without fear of peritoneal faecal contamination and, in the absence of a persisting distal anatomical or functional obstruction, the fistula heals quickly and often within days.

SURGERY FOR LOWER GASTROINTESTINAL TRACT HAEMORRHAGE

Lower gastrointestinal tract haemorrhage is common and usually self-limiting and most patients do not require any surgical intervention. In some patients, haemorrhage is profuse and life threatening and surgeons are involved in the diagnosis and management. Occasionally, the cause of profuse lower gastrointestinal haemorrhage is obvious; the patient may have severe colitis or a history of a recent haemorrhoidectomy. More often, the underlying pathology is obscure. The patient is classically middle aged or older, and the most common source of the haemorrhage is either an eroded vessel at the neck of a sigmoid diverticulum or an ulcerated angiodysplastic lesion in the submucosa of the right colon. A spontaneous large haemorrhoidal bleed is another possibility. A major proximal gastrointestinal haemorrhage can also result in a patient passing profuse fresh blood through the anus, and an upper gastrointestinal source should be excluded by upper gastrointestinal endoscopy, if available.

TREATMENT

The first priority is adequate resuscitation followed by gastroscopy to exclude upper gastrointestinal pathology. Patients on anticoagulation drugs should have the drugs stopped and reversal agents commenced to stem the bleeding. Surgical intervention can usually be avoided, as 90% of patients with profuse lower gastrointestinal haemorrhage will stop bleeding spontaneously. The cause of the haemorrhage may never be elucidated, even after extensive investigations, but fortunately major bleeding seldom recurs.

A *colonoscopy* can be difficult, as the blood obscures the view. A *flexible sigmoidoscopy*, undertaken without a prior enema, can sometimes be helpful. If the sigmoidoscope can be passed into the colon proximal to the luminal blood to where there is normal stool, this indicates that the bleeding is from the anus or rectum. This information has prevented the occasional inappropriate colectomy for severe haemorrhoidal bleeding.

If profuse bleeding continues and surgery seems inevitable, a preoperative angiogram, if available, can be performed to elucidate the site of the bleeding, as this often remains obscure even at laparotomy. CT angiography is an alternative diagnostic test to conventional angiography, but does not allow embolisation if a bleeding vessel is seen. However, CT is more readily available, as no arterial catheterisation is required. Colonic arterial embolisation must be precise, and distal in the arterial tree, or there is an increased risk of a patch of non-viable colon developing and rupturing several days later. Angiography will be helpful only if bleeding is occurring at a rate greater than 0.5–1.0 mL per minute. Unfortunately, although the bleeding is usually intermittently much higher in volume than this, angiography performed between brisk bleeds will add no information.[16]

If angiography is unavailable or is unhelpful, the surgeon may be forced to operate without a diagnosis. Occasionally, a bleeding Meckel's diverticulum or other obvious pathology is identified at laparotomy, but more often there is no visible or palpable evidence of the site of bleeding. An on-table endoscopy is a useful adjunct during the operation, even if preoperative endoscopy attempts were unsuccessful at localising disease. The surgeon has the advantage of guiding the bowel over the endoscope in a more thorough fashion and intestinal contents can be cleared more effectively at operation. An endoscopic lesion can be tackled by oversewing of the lesion (if a biopsy or resection is not warranted) or excision as appropriate. Mild diverticular disease of doubtful significance is noted, and the whole colon is full of blood. Blood in the right colon does not confirm a more proximal source of haemorrhage, as it may have refluxed from the left side. The differential diagnosis is thus still between angiodysplastic bleeding, which is more common from the right colon, and diverticular bleeding from the left. A blind right or left hemicolectomy leaves the patient at high risk of requiring a second major laparotomy within 48 hours. A subtotal colectomy and ileostomy is now the recommended procedure in this situation. The risk of further haemorrhage is significantly reduced, but at the expense of a more major initial resection. A second elective laparotomy is still required to restore intestinal continuity with an ileorectal anastomosis. However, if there is a further haemorrhage after a colectomy and ileostomy, it will be obvious whether it is from the rectum or from the proximal gastrointestinal tract.

A transverse 'split colostomy', where the two ends of the divided transverse colon are brought out as separate stomas with an intact skin bridge between, can occasionally be a useful diagnostic measure in a patient who has temporarily stopped bleeding but in whom the aetiology remains obscure. Any subsequent haemorrhage will then immediately identify whether the bleeding is from the right or left colon. A further laparotomy for a hemicolectomy may be required, but the patient will not need to lose the whole colon.

MESENTERIC ISCHAEMIA

Mesenteric ischaemia is a condition resulting from inadequate perfusion of the bowel. The blood flow may be completely occluded by an arterial thrombus or embolus. Ischaemia may also result from a reduced flow due to non-obstructive pathologies such as non-occlusive mesenteric ischaemia. The presentation of mesenteric ischaemia may be acute or chronic. *Acute mesenteric ischaemia* presents as an intra-abdominal intestinal emergency with a high mortality rate, especially as bowel infarction has usually occurred before laparotomy. The clinical presentation is variable, but pain and elevation of the white cell count are often disproportional to the clinical findings. *Chronic mesenteric ischaemia* presents as post-prandial abdominal pain, fear of eating and weight loss. Patients may also present acutely with thrombosis on a background of chronic ischaemia (acute on chronic presentation).

MANAGEMENT CONSIDERATIONS IN MESENTERIC ISCHAEMIA

The management of mesenteric ischaemia requires multidisciplinary input. Often, the precipitating lesion can be treated by endovascular techniques. Depending on the nature of bowel involvement (e.g. infarction), surgery may be required. In acute settings, with obvious peritonitis, bowel resection is needed. Generally, a bowel anastomosis is not performed at the initial operation for mesenteric ischaemia, as the viability of the remnant ends of the bowel is uncertain and a larger resection to obtain definitely viable bowel risks the development of short bowel syndrome. The recommended procedure is to staple off or suture the ends of the bowel after resection and plan a second-look laparotomy to address any remaining non-viable bowel. If second-look surgery is not planned, both ends should be brought out as a stoma proximally and the distal bowel as a mucous fistula. This allows inspection of the bowel ends' viability or progressive ischaemia. The decision-making around the intra-operative management of mesenteric ischaemia is complex and a second opinion, from an experienced colleague, is recommended. A second opinion may optimise the decision-making and improve outcome in this devastating situation.

The vascular pathology, for example a major arterial stenosis, needs to be addressed, after the infarcted bowel has been resected, to prevent progression of the ischaemia. This is increasingly being managed endovascularly and either the patient needs to be transferred to a vascular centre or a vascular surgeon should be available if open surgery is contemplated.

Mesenteric ischaemia causes significant and life-threatening morbidity, and care must be taken to address this as quickly as possible in the preoperative period. If a significant length of small bowel is removed, the patient may need to be on total parenteral nutrition (TPN), either temporarily until intestinal adaptation occurs or, on occasion, as lifelong TPN. Intestinal adaptation may take up to a year to fully compensate small bowel function for the loss of length. Long-term TPN sometimes fails due to the loss of venous access or metabolic problems and a selected group of such patients may be suitable for intestinal transplantation as the final option. However, many patients may have recurrent events through the course of their life and this will further compromise efforts to preserve bowel length and function.

It is prudent to realise that the majority of patients with acute mesenteric ischaemia are frail and are generally older people, and many have multiple other comorbidities. The finding at laparotomy of infarcted small bowel in these patients is generally not amenable to patient salvage and an informed decision to not resect and close the abdomen may be prudent and in the best interests of the patient and family.

MESENTERIC EMBOLUS

An embolus should be suspected in any patient with an acute abdomen who is in atrial fibrillation. Other potential sources of embolus include mural thrombus in the heart after a myocardial infarction and atheromatous plaques in the proximal aorta. The clinical presentation is classically described as a triad of severe abdominal pain, diarrhoea and the presence of a source for the embolus. At laparotomy, pulsation is classically preserved in the proximal superior mesenteric artery, and the ischaemia does not extend the whole length of the bowel supplied by the artery. This is a result of the embolus lodging where the artery narrows after it has given off the middle colic artery and the first of its jejunal branches. Infarcted bowel must be resected, but ischaemic bowel can be reperfused.

The superior mesenteric artery is identified and isolated at the root of the small bowel mesentery, as approaching the superior mesenteric artery flush with the aorta is very difficult. An embolectomy is preferably performed via a longitudinal rather than a transverse arteriotomy and a vein patch used for closure, as the orientation of the incision does not compromise the distal anastomosis of a salvage bypass graft if this proves necessary. Increasingly, endovascular techniques are being used to aspirate or thrombolyse the clot.

Patchy, widespread necrosis due to multiple emboli, either from an ulcerated plaque within the superior mesenteric artery itself or from the adjacent aorta, is a particularly difficult situation, often requiring multiple laparotomies to check the state of the bowel.

MESENTERIC ARTERIAL THROMBOSIS

This is the most common mesenteric intravascular catastrophe. There may be a background of chronic mesenteric ischaemia with weight loss, abdominal pain and often negative abdominal and gastrointestinal tract investigations. The acute occlusion is usually a thrombus on an atheromatous plaque located at the origin of either the superior mesenteric artery or the diffuse thrombosis in the proximal few centimetres of the vessel. The bowel may therefore be affected from within a few centimetres of the duodenojejunal flexure to the splenic flexure, and there is no palpable pulsation in the proximal superior mesenteric artery. However, the gut is often variably affected in a segmental way, as collateral pathways may lead to a distribution of ischaemic changes that only loosely follow the arterial territories. The surgeon must consider, firstly, if there is enough viable bowel to allow resection and anastomosis without revascularisation; secondly, if revascularisation is indeed an option and, thirdly, what the safest options are of resection, rejoining or second-look laparotomy. Some surgeons advocate that relaparotomy is mandatory with stapling of the bowel ends to force a second look after 24 hours. This overrides a strong temptation not to return to theatre if the patient shows early improvement.

Emergency revascularisation is difficult and complex but a bypass graft, or a thrombectomy combined with angioplasty and/or stents, can be attempted[17] (see Chapter 18). The choice of option is easier if preoperative imaging includes a CT angiogram. If CT is available and mesenteric ischaemia is suspected, an arterial phase contrast study should be requested.

MESENTERIC VENOUS THROMBOSIS

Mesenteric venous thrombosis may occur secondary to intra-abdominal trauma, sepsis or malignancy, or in association with portal hypertension. It may occur as a primary event in patients with severe dehydration or other acquired thrombophilia states. In the more chronic presentation, the diagnosis may have been established by a CT scan with portal phase imaging or ultrasound. Surgery can often be avoided by treatment with heparin or thrombolysis. However, in some cases, the presentation is more acute and the diagnosis is made at laparotomy with venous infarction of the small bowel already established. The thrombosed veins are visible and arterial pulsation in the mesentery may still be present. Resection of infarcted bowel is essential, and thereafter the treatment is with heparin to prevent further propagation of thrombus. As in mesenteric arterial ischaemia, a second-look laparotomy at 24 hours to check if there has been no extension of thrombosis is recommended, with the resected bowel ends closed by a mechanical stapler and any anastomosis delayed until viability has been established.

Endovascular options are possible but seldom available in routine clinical practice. Endovascular access requires venous access by the percutaneous transhepatic or transjugular intrahepatic portosystemic shunt route. In some patients, thrombectomy or thrombolysis can be carried out using an intravenous catheter.[18]

POSTOPERATIVE CONSIDERATIONS

For any mesenteric catastrophe, an extensive resection of small bowel, often with the additional removal of the right colon, may be necessary. An anastomosis can be performed, but the resultant profuse diarrhoea may make the early postoperative period very problematic. An alternative to re-anastomosis is to bring out the proximal end as a jejunostomy. This stoma will be of high output, and absorption from the colon will be lost until the bowel is rejoined, but the fluid and electrolyte losses can be measured and the perineal skin spared from the erosive effects of high-volume, irritable diarrhoea. The long-term problems of intestinal failure are discussed in Chapter 3, but they may prove insurmountable in a frail older patient, and closure of the abdomen, without any bowel resection, may be the best outcome for the patient and relatives.

NON-OCCLUSIVE MESENTERIC ISCHAEMIA

Ischaemia can result from reduced flow without occlusion of vessels. This occurs in patients who have hypotension for a variety of reasons. The use of inotropes in these situations may also contribute towards vasoconstriction. Many patients may also have concomitant stenotic arteries that may compromise bowel perfusion in the presence of hypotension. Non-occlusive mesenteric ischaemia has also been described in cocaine abusers. Treatment measures focus on correcting the underlying condition leading to hypotension. In some patients, raised intra-abdominal pressures may contribute to bowel ischaemia and a decompression laparotomy will help by reducing the pressure on the mesenteric vessels.

ISCHAEMIC COLITIS

Ischaemic colitis is a segmental ischaemic involvement of the colon resulting from changes in the local mesenteric vasculature or due to non-occlusive ischaemia. The most common colonic site is in the region of the splenic flexure, the watershed between the superior mesenteric and the inferior mesenteric arterial blood supply.

Angiographic findings are often lacking or inconsistent with clinical findings. The primary management is medical treatment. Emergency surgery is warranted if there is bowel gangrene, massive bleeding, fulminant colitis or inadequate response to medical therapy. In the chronic setting, surgery may be required to treat colonic strictures.

Left-sided ischaemic colitis

This condition is common, but fortunately it is usually focal and seldom progresses to full-thickness infarction. Classically, the patient has left-sided abdominal pain followed by bloody diarrhoea. The ischaemic colitis occurs most commonly around the splenic flexure or in the descending colon, and the classical X-ray appearance of 'thumb-printing' from mucosal oedema may be present. Left-sided colitis can occur spontaneously on a background of atherosclerosis, and a variant is also seen after aortic surgery, when the inferior mesenteric artery has been ligated. The perfusion of the sigmoid colon may then be inadequate, as arterial supply is dependent on the marginal artery around the splenic flexure (see Figure 13.2).

Mucosal ischaemia, and even mucosal infarction, can be treated conservatively, and surgery can usually be avoided. However, if there is evidence of full-thickness bowel wall infarction, a laparotomy is needed and non-viable colon must be resected. A left-sided colonic anastomosis with marginally ischaemic bowel must be avoided, and a Hartmann's procedure may be preferable. The proximal colon is brought out as an end colostomy. The distal resection will generally be to the level of the peritoneal reflection to ensure adequate perfusion, and should be marked with a long, non-absorbable suture to ease identification at a subsequent operation if restoration of continuity is performed at a later date.

Right-sided ischaemic colitis

This is most often encountered in patients with serious underlying medical pathology and is associated with a high mortality.[19] Any form of vasculitis can produce a locally ischaemic patch of bowel that can progress to ulceration and haemorrhage or infarction and perforation. A more extensive form of right-sided ischaemic colitis is encountered in immunosuppressed patients receiving cytotoxic chemotherapy. Neutropenia is probably the most important aetiological factor. If perforation or infarction occurs, laparotomy is needed. Usually, the safest procedure is a right hemicolectomy, but without an ileocolic anastomosis. The distal ileum is brought out as an ileostomy and the transverse colon as a mucous fistula. This is a safer option in ill patients than leaving the distal end as a closed colonic stump within the peritoneal cavity.

SURGERY FOR INFLAMMATORY BOWEL DISEASE

Ideally, patients with inflammatory bowel disease are managed jointly by gastroenterologists and surgeons, as the decisions about if and when to operate can be complex. Recent advances in medical treatment of inflammatory bowel disease will save some additional patients from surgery, but may result in others having their surgery needlessly delayed or undertaken in a suboptimal, immunocompromised state. Inflammatory bowel disease includes ulcerative colitis and Crohn's disease, as well as an indeterminate variety that shows features of both diseases. It may be best for the surgeon to view any indeterminate disease as Crohn's disease when considering the surgical options.

ULCERATIVE COLITIS

The inflammation in ulcerative colitis is confined to the large bowel, and ulcerative colitis is a colonic mucosal disease. The excision of all large bowel mucosa offers a cure, but at a price that is frequently unacceptable, particularly in patients with mild to moderate disease. Many patients are managed completely and successfully with medical treatment, but others will require emergency, urgent or elective surgery. The majority of patients requiring surgery for ulcerative colitis are keen to avoid a permanent stoma, and this can be achieved by ileoanal pouch reconstruction. Pouch reconstruction surgery is complex, with variable functional results and both early and long-term complications. Outcomes after ileoanal pouch surgery are consistently better in the hands of coloproctologists who have developed a particular interest. Referral to these surgeons is therefore recommended.

Urgent and emergency intervention

Close cooperation between surgeons and gastroenterologists is essential, as patients may deteriorate despite intensive medical management. Once colectomy can be predicted as inevitable, delay will merely increase the complications of surgery in patients who are physiologically deteriorating and immunosuppressed by steroids and other immunosuppressive medication. Surgery can usually be a planned procedure, within a few days of this decision, but occasionally true emergency intervention is necessary. Urgency is increased if toxic dilatation of the colon occurs, as the viability of the colon is threatened and toxins and bacteria enter the circulation. Colonic perforation will inevitably follow untreated toxic megacolon, and occasionally surgery has to be undertaken when perforation has already occurred. A caecal diameter of 10 cm, as measured on an abdominal X-ray, indicates that improvement without surgery is unlikely. A transverse colon diameter of more than 6.5 cm may be a more sensitive measure of toxic dilatation and the need for urgent surgical intervention.

Generally, only the colon is removed and proctectomy, as an emergency, is usually unnecessary, as proctectomy increases the magnitude of the procedure and makes future pouch reconstruction more difficult. A total colectomy, with rectal preservation and a terminal ileostomy, is the standard procedure.

However, when emergency surgery is required in patients in whom haemorrhage was the predominant indication, a total proctocolectomy may be required, as bleeding is most frequently from the rectum. The anus should be preserved if a future pouch is a possibility.

It is important that any patient with a retained rectum is aware of the long-term risks of rectal cancer. Many are reluctant to have the proctectomy, especially if they are symptom free, and are not contemplating a pouch reconstruction. They must be advised of the importance of regular screening of the rectal stump.

Elective intervention for ulcerative colitis

Persistent symptomatic disease Persistent symptomatic disease despite medical management is an indication for proctocolectomy. If the patient is unsuitable for a pouch reconstruction, or does not wish to have one, a proctocolectomy and end ileostomy can be performed as a single procedure. If a pouch is to be considered, the proctectomy and pouch formation are better postponed until the patient is off steroids or any other immune modulators and has regained good nutritional status, as the complications of pouch surgery increase if a pouch is performed in suboptimal conditions. In young women, major pelvic surgery carries a significant risk of subsequent infertility[20] and the option of further delaying proctectomy and pouch reconstruction until after the patient has completed her family should be discussed.

Occasionally, a subtotal colectomy and ileorectal anastomosis is considered in a patient with apparent rectal sparing. There are anecdotal reports of long-term successes, but it is generally an unsatisfactory solution for ulcerative colitis, as the rectum is invariably involved, to some degree, and may deteriorate rapidly during the months following an ileorectal anastomosis.

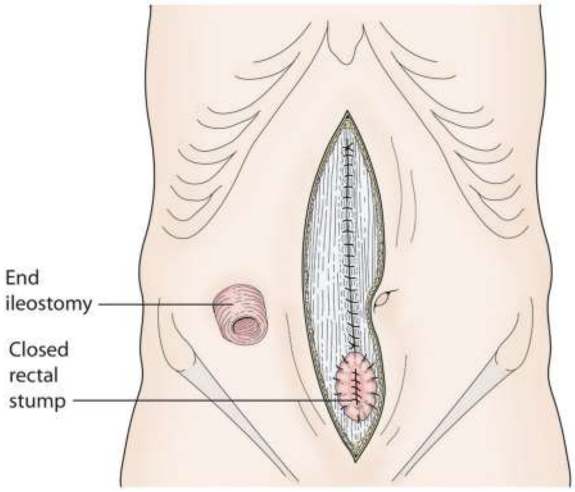
Dysplasia Patients with pancolitis of more than 10–20 years' duration have a significantly increased risk of cancer. Many are relatively symptom free on minimal maintenance treatment. They are therefore reluctant to consider surgery and prefer regular colonoscopic surveillance with biopsies, only agreeing to colectomy when dysplasia has been demonstrated. The proctocolectomy can be combined with the formation of an ileal pouch in this situation.

TOTAL COLECTOMY

A total colectomy operation may be combined with a proctectomy and, in some patients, an ileoanal pouch reconstruction. A total colectomy can be performed by open or laparoscopic surgery, although an open operation is usually the safest option when there is toxic dilatation. The ascending, descending and sigmoid colon are elevated on their respective retroperitoneal mesenteries and the resection is a combination of right, transverse and left hemicolectomies, as described in Chapter 14. In this situation, the colectomy is an operation for benign disease and the resection does not have to include a radical lymphadenectomy. The mobilisation can therefore be more conservative and need not extend to the root of the mesentery. The superior rectal artery may be preserved, as in a sigmoid colectomy for diverticular disease, and this is important if the rectal stump is to be left long enough to be brought up to the abdominal wall. Ligation of the mesentery can be close to the bowel wall but, as this requires ligation of multiple vessels, it is usually preferable to choose a somewhat more proximal site (see Figure 13.2). If the colectomy is for long-standing colitis with dysplasia, the danger of an occult malignancy in the colon must be considered and, in this situation, a more radical lymphadenectomy with high arterial vascular ligations is advisable.

The omentum can be left *in situ* in a total colectomy for benign disease, but the omentum has been implicated in the frequent adhesive obstructions that some patients suffer after a total colectomy. For this reason, some surgeons advocate removal of the omentum. Additionally, in an emergency colectomy for severe ulcerative colitis, the colon is friable and will perforate easily, and there may be undue difficulty in entering the plane between the transverse colon and the greater omentum. It is safer to divide the omentum along the greater curve of the stomach between ligatures and remove the omentum *en bloc* with the colon. Energy devices, if available, facilitate omentectomy and division of the large bowel mesentery in both open and laparoscopic surgery.

The superior rectal artery is preserved, and this enables the rectal stump to be left long. This is advantageous, as an intraperitoneal closed rectal stump with severe disease may perforate, and it is safer to bring out the proximal end of the retained bowel as a mucous fistula. An alternative is to attach the closed rectal stump to the fascia at the lower end of the midline wound (Figure 13.13) and leave the



13.13 The linea alba of this midline wound has been closed, except for the distal few centimetres, where the edges of the fascia have been sewn around the closed rectal stump. The skin directly over the stump is left open. ⏎

overlying skin open. If the colectomy was performed laparoscopically, the small suprapubic wound for the delivery of the colon can be used. The skin will heal over rapidly if the stump closure remains secure, avoiding the long-term inconvenience of a mucous fistula. However, if the stump 'blows', a mucous fistula should form without peritoneal contamination. This technique is often referred to, somewhat inaccurately, as 'a closed mucous fistula'. The terminal ileostomy is fashioned as described in Chapter 14.

PROCTECTOMY

When a proctectomy is an extension of a total colectomy, the dissection planes around the mobilised sigmoid colon lead naturally into the plane around the mesorectum. Similar conditions prevail when a long rectal stump has been left under the abdominal wound at an earlier total colectomy. Planes can be more difficult to define when a short rectal stump has been left behind, and the stump will usually collapse down and adhere to neighbouring structures deep in the pelvis. The operation to excise the rectum for rectal cancer is described in Chapter 14. When pelvic surgery is undertaken for benign disease, there is considerable emphasis on preservation of the pelvic autonomic nerves. Some surgeons therefore favour a *close rectal dissection*, as the dissection will be kept well away from the nerves. This consists of excision of the rectum, leaving the mesorectum mainly *in situ*. Additional advantages include a smaller pelvic 'dead space' into which the small bowel may prolapse and a supporting surround of fat for an ileoanal pouch. Multiple ligations of mesorectal vessels on the rectal wall are required, and access deep in the pelvis becomes progressively more difficult, as the mesorectum is still filling the pelvis and tethering the remaining rectum into the hollow of the sacrum. Other surgeons therefore prefer to follow the same precise anatomical plane around the mesorectum used in an anterior resection for cancer, carefully identifying and preserving the nerves. However, during the final part of the dissection, most 'cone in' through the distal mesorectum to reduce the risk of injury to the autonomic nerves. This 'total mesorectal excision type' dissection is more anatomically elegant, with less bleeding, and if there is an unsuspected rectal cancer associated with the colitis, oncological clearance is more likely to have been achieved.

The dissection of the anal canal varies depending on whether a pouch is planned or whether a pouch–anal anastomosis is to be hand sutured or performed with a circular stapling device. However, in all situations all of the columnar epithelium must be excised to eradicate the disease.

If the patient is to have a *permanent ileostomy*, the final dissection is completed from the perineum by dissection in the intersphincteric plane, which is developed from the anal verge and followed proximally to join the pelvic dissection (see Chapter 14). The rectum and anus are removed but, in contrast with the abdominoperineal excision described in Chapter 14, there is no cuff of external sphincter or ischiorectal fat attached to the bowel, and there is a much smaller perineal wound.

When a pouch is planned by a *stapled anastomosis to the anal canal*, the final dissection for the proctectomy is a similar technique to that described in Chapter 14 for a very low anterior resection, but with the modifications already discussed above. It is important that a cuff of columnar epithelium is not left *in situ*, as it may result in persistent inflammation, poor pouch function and a continuing risk of malignant change. Transection of the anal canal, followed by a circular stapled anastomosis, will result in a staple line at the dentate line, and the final cuff of transitional mucosa will have been excised as the distal 'doughnut'. The final deep dissection to achieve this is technically difficult, especially in an obese male patient. A close rectal dissection technique may make access even more difficult. In addition, these very low stapled anastomoses are associated with inevitable excision of the proximal part of the internal sphincter (see Chapter 14), which may prove crucial for the passive continence of the semi-liquid pouch effluent. For both these reasons, some surgeons prefer a mucosectomy followed by a sutured pouch–anal anastomosis.

When a pouch is planned by a *hand-sutured anastomosis to the anal canal*, the rectum is divided several centimetres above the dentate line. The anorectal stump is retained, but is then denuded of all columnar epithelium (mucosectomy). The surgeon, working from the perineum, inserts an anal retractor and injects 1:200,000 adrenaline submucosally to lift the mucosa away from the muscle wall. The mucosa is then excised from just above the dentate line up to the rectal division. In severe colitis, the mucosa is friable and haemorrhagic and will have to be excised in strips. It is very important not to leave any mucosa behind and to obtain complete haemostasis.

ILEAL POUCH

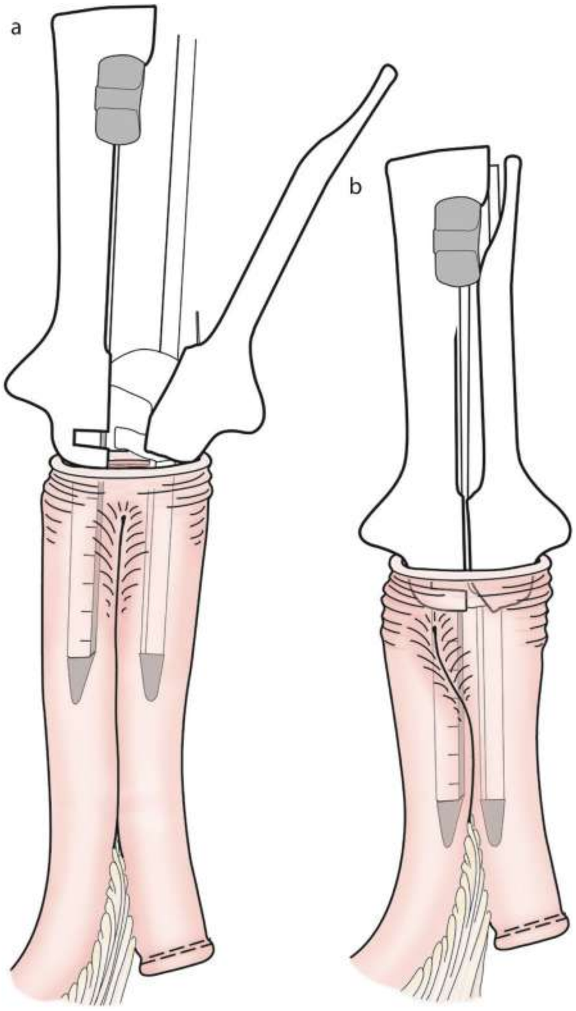
The terminal loop of ileum is inspected for suitability and, in particular, the apex of the loop must be able to reach to the anus without tension.[21] In a laparoscopic proctectomy, this must be checked before the incision is made to deliver the specimen and bring the terminal ileum outside the abdomen to create the pouch. A J-pouch, formed by folding back the terminal ileum on itself, is the simplest. An anastomosis is formed between the two limbs of the loop, each of which should be between 15 and 20 cm in length. Thus, 30–40 cm of terminal ileum is needed for the pouch. The pouch can be constructed very simply with a mechanical stapling device introduced through a small enterotomy at the apex of the loop (Figure 13.14a). It is helpful to apply lubricating gel on the stapler, which facilitates passage into the bowel. Stay sutures help to support the ileum, and a finger swept between the blades of the stapler, before it is closed, ensures that the small bowel mesentery is out of the staple line. A second or third firing of the GIA™ 80 stapler is necessary (Figure 13.14b). Some surgeons prefer a hand-sewn pouch, whereby the small bowel loops are sutured together, although there appears to be little advantage and it is more time consuming. A variety of different pouches have been tried and hand-sutured W- and S-pouches were briefly popular but have been largely abandoned, as pouch function was inferior. In particular, the S-pouch was associated with evacuatory difficulties and has been abandoned.

Stapled ileal pouch–anal anastomoses

A stapled ileoanal pouch anastomosis is performed in a similar fashion to the coloanal anastomosis described in the section on anterior resection of the rectum in Chapter 14.

Hand-sutured ileal pouch–anal anastomoses

The pouch is sutured transanally after a mucosectomy. The orientation of the pouch is decided from the abdominal views, and any rotation of the afferent ileum must be avoided. A suture is then passed through the distal opening of the pouch at the 3 o'clock position and the needle is passed down through the anus to the perineal operator. This procedure is then repeated at the 9 o'clock position. The pouch is now guided down into the pelvis, and the surgeon passes the needles through the anal mucosa at the lower edge of the mucosectomy in the 3 and 9 o'clock positions. As these two sutures are tied, the pouch is fixed to the anus in the correct orientation and lies within the internal and external sphincters. A small bite of internal sphincter should be included to avoid the suture tearing through the mucosa. The perineal operator then hand sews the whole circumference of the pouch opening to the dentate line,



13.14 Formation of an ileal pouch. (a) The blades of the stapler are introduced through an enterotomy at the apex of the ileal loop. One blade is inserted into each limb of the bowel, the two blades are locked together, the mesentery is rotated out of the line of the staples and the device is closed and fired. (b) The stapler is reloaded, introduced into the pouch and then advanced into the remaining separate limbs. A second or third firing completes the pouch. ⏎

using fine, interrupted, absorbable sutures. Access for per-anal surgery is always limited, and care must be exercised in anal retraction, as excessive dilation will stretch or disrupt the sphincters.

SURGERY FOR POUCH COMPLICATIONS

Ileoanal pouches have complications and, by 10 years, in about 20% of cases, either they have been removed or the pouch has been defunctioned by a stoma. Revision pouch surgery is often disappointing, but better results are obtained by referral to surgeons with a special interest in pouch surgery. A pouch may have to be revised if there are repeated episodes of inlet or outlet obstruction, or surgery may be undertaken for fistulous complications.[22] Outlet obstruction can be treated by a pouch advancement from below, but any more major pouch revision will require a pelvic dissection from above. The development of a fistula often means that the pouch is doomed to fail. Some fistulae occur during the immediate postoperative period, in association with pelvic sepsis, but others occur years later in an otherwise trouble-free pouch. A late fistula is frequent and an almost inevitable eventual complication if a pouch is constructed in a patient where the background colitis is Crohn's disease or an indeterminate colitis. A fistula into the bladder or into another intra-abdominal organ is repaired from above, and this is also the approach for an extrasphincteric fistula to the perineum. The more common intersphincteric and trans-sphincteric fistulae are also difficult to treat in a patient with a pouch. Scarring from previous surgery makes any flap advancement technique less feasible, and the already precarious continence in these patients may be lost by any sphincter sacrifice. A drainage seton may be the most prudent procedure, but a repair may have to be attempted for a symptomatic pouch–vaginal fistula (see Chapter 15). Often, the pouch must be defunctioned again with a loop ileostomy while further attempts at pouch salvage are pursued. The original histology should be reviewed and, if there are any features of Crohn's disease, further efforts to save the pouch will most likely prove futile.

A pouch may have to be excised for poor function, fistulous complications or intractable pouchitis. The final one is more common in pouches created for inflammatory bowel disease than in patients in whom the indication was polyposis. The excision of a pouch is along similar lines to a proctectomy, but planes may be difficult to follow. If a replacement pouch has to be fashioned, a further 30–50 cm of small bowel has to be sacrificed. Occasionally, this will be contraindicated if there is inadequate small bowel length for absorption.

CROHN'S DISEASE

In contrast with ulcerative colitis, Crohn's disease can affect the gastrointestinal tract from the mouth to the anus and, therefore, surgery can never guarantee disease eradication. However, in patients with localised pathology, excision of all symptomatic disease may provide long-term benefits. The bowel involvement is classically patchy, with segments of inflamed bowel separated by lengths of normal bowel. The inflammation is transmural and, in addition to the mucosal ulceration and haemorrhage that are also seen in ulcerative colitis, deeper oedema or scarring can obstruct the bowel lumen. The inflamed serosal surface of an involved segment may also adhere to an adjacent organ, with subsequent fistulation.

Colonic Crohn's disease

This condition may present with very similar features to those of ulcerative colitis and, again, surgery may have to be considered in both the emergency and the elective settings when medical management fails. The long-term cancer risk is similar to that in long-standing ulcerative colitis, and colonoscopic surveillance can be hampered by a more distal Crohn's colonic stricture. Total proctocolectomy with a terminal ileostomy is the preferred option if the rectum or anus is also involved. A colectomy and ileorectal anastomosis may be a satisfactory alternative in Crohn's colitis with rectal sparing. An ileoanal pouch carries an unacceptably high risk of fistulous complications and should, in general, be avoided.

A defunctioning loop ileostomy can be an excellent temporary measure in severe Crohn's colitis. Intensive medical treatment is continued and, if remission is achieved, the ileostomy can be closed. In practice, this is seldom recommended, as relapse is almost inevitable, but the patient has the opportunity to experience life with a temporary stoma before making a final decision regarding proctocolectomy.

Terminal ileal Crohn's disease

This is the most common form of the disease, and resection by a limited right hemicolectomy may be preferable to long-term medical management with steroids and immunosuppression. This is particularly the situation in the adolescent in whom growth and development into adult life are stunted by postponing what is often inevitable surgery. There may be no evidence of other areas of gastrointestinal Crohn's disease, and 60% of patients will have no further trouble. Even those who do develop further active disease may have several symptom-free years. Cessation of smoking and continuation of treatment with mesalazine reduce the incidence of further problems, but there is now some evidence that surgical technique may also be important, as outlined below.

Terminal ileal Crohn's disease, coexistent with appendicitis, is occasionally a difficult operative dilemma. An inflamed appendix with a normal caecum can be treated by an appendicectomy, whereas an inflamed appendix secondary to Crohn's inflammation of the caecal pole will require a right hemicolectomy. More difficult to assess is the non-inflamed appendix and the surprise finding of a thickened inflamed terminal ileum, which, although probably Crohn's disease, could be a *Yersinia* ileitis or a lymphoma. The presence of 'fat wrapping' supports a clinical diagnosis of Crohn's disease, as it is not a feature of lymphoma or the acute ileitis of *Yersinia*.

A right hemicolectomy for terminal ileal Crohn's disease is a more limited resection than that for a caecal cancer, as described in Chapter 14, because no lymphadenectomy is necessary. However, any loops of small bowel adherent to the inflammatory mass must also be excised. The terminal ileal involvement normally ends at the ileocaecal valve, and the aim of surgery is to remove only the diseased segment, as recurrence proximal to the anastomosis is not prevented by a more radical excision of normal adjacent ileum. The method of anastomosis does, however, appear to influence recurrent disease, and a wide side-to-side stapled anastomosis may be preferable to the traditional sutured end-to-end anastomosis. It is uncertain whether the benefit is related to the width of the anastomosis and the avoidance of any hold-up or whether staples are less irritant than sutures. Certainly, any sutured anastomosis in Crohn's disease should be created with absorbable sutures, and silk, in particular, is best avoided.

Crohn's disease obstruction

Crohn's obstruction may result from inflammatory oedema during an acute exacerbation. Clinical decisions are difficult, as the full-thickness inflammation inevitably produces localised signs of peritonism and the exclusion of a strangulated loop is difficult. Surgery can usually be avoided: the obstruction is treated conservatively and the exacerbation of Crohn's inflammation managed with steroids. Chronic fibrous strictures causing partial obstruction of either the small or the large bowel are better managed by limited resection or by stricturoplasty. Endoscopic dilatation of these strictures is now another option. A stricturoplasty is carried out by incising the antimesenteric border of the small bowel longitudinally across the stricture and then closing the resulting defect transversely. This has the advantage of preserving the full length of the small bowel, and recurrent Crohn's obstruction at a stricturoplasty site is less frequent than at a small bowel anastomosis. When a diseased segment is too long for a stricturoplasty, a small bowel resection should be carried out, but consideration must be given both to preservation of adequate lengths of small bowel (see Chapter 7) and to the inadvisability of performing an anastomosis in diseased bowel. However, it should be remembered that malabsorption can be due to colonisation of partially obstructed small bowel and to an inadequate length of residual small bowel.

Crohn's fistulae

Crohn's fistulae may occur into another loop of bowel or into the bladder or the skin. Treatment is by resection of the fistula and repair through, and using, healthy tissue, if possible. Diversion of faecal contents may sometimes be the only practical surgical option.

Crohn's disease of the anus

This condition is discussed in Chapter 15.

SURGERY FOR INTESTINAL INFECTIONS AND INFESTATIONS

Treatment of intestinal infections and infestations is by medical therapy, and surgery is only indicated for complications such as haemorrhage, obstruction or perforation. Often, however, the diagnosis has not been suspected preoperatively. Frequently, an ischaemic loop of bowel has been suspected, but at operation the peritonism is found to be from the inflammatory process involving the peritoneum. No bowel resection is indicated if the bowel is viable. The abdomen is closed and appropriate medical treatment is commenced. When there is no firm diagnosis, the patient is in danger of inappropriately radical surgery. This may be inevitable, especially if malignancy is suspected, but the surgeon must always consider the possibility of infective pathology. On other occasions, there may be a preoperative diagnosis, but a complication of the infection requires surgical intervention.

Ascariasis (roundworms)

Ascaris lumbricoides obstruction was discussed earlier in this chapter in the 'Intraluminal obstruction' section.

Tuberculosis

Abdominal tuberculosis is a common cause of obstruction in endemic areas,[23] from either a 'plastic peritonitis' or a mass of tuberculous glands to which bowel is adherent. A side-to-side bypass is often the most appropriate operative solution. Other presentations include abdominal pain and ascites and small bowel perforations.[24] It is important to differentiate tuberculosis from inflammatory bowel disease. The features that favour a diagnosis of tuberculosis over Crohn's disease are fever, night sweats and ascites. On endoscopy, the presence of transverse ulcers, a patulous ileocaecal valve and the presence of pseudopolyps all favour a diagnosis of tuberculosis. The presence of healed or active lesions on a chest X-ray and the presence of necrotic nodes are also strongly in favour of tuberculosis. If a preoperative diagnosis can confidently be made, then the addition of antitubercular drugs may avoid surgery.[25]

AMOEBIASIS

Infection with *Entamoeba haemolytica* can cause a toxic dilatation similar to that seen in ulcerative colitis. It can also produce a local inflammatory mass, or *amoeboma*, in the caecum and this can mimic a caecal malignancy. If a diagnosis of amoebiasis has been made, surgical resection is indicated only for a complication such as obstruction, perforation or toxic dilatation. These complications should be avoidable, unless the diagnosis and appropriate medical treatment have been delayed.

TYPHOID

Typhoid ulcers form over the affected small bowel lymphatic tissue (Peyer's patches) during the third week of untreated typhoid fever. Intraluminal haemorrhage, a walled-off perforation with an associated intraperitoneal abscess, and free perforation with generalised peritonitis may all occur. Late presentation and the poor general health of these patients partly account for the high mortality.[26] Some surgeons advocate resection, but oversewing the perforation is usually adequate.

CYTOMEGALOVIRUS INFECTION

Infection with this organism usually occurs in immunocompromised patients and may produce an acute inflammatory lesion, which can bleed, perforate or obstruct. It is also seen in patients with active inflammatory bowel disease. The most common site is in the descending colon, just below the splenic flexure. Treatment is medical, unless a surgical complication ensues.

PIGBEL

Pigbel is a necrotising jejunitis with the underlying pathology infection by *Clostridium perfringens.* Treatment of mild cases is with antibiotics and fluid resuscitation but, when more severe, a laparotomy and resection of the necrotic bowel may be needed. Necrotising jejunitis of idiopathic origin has also been reported.

YERSINIA INFECTION

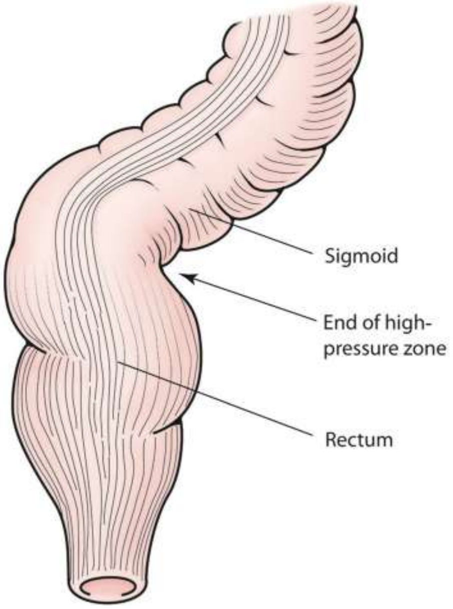
Yersinia spp. can cause an acute terminal ileitis, which may be difficult to differentiate from the terminal ileitis of Crohn's disease. The short history and the absence of the classical fat wrapping of Crohn's disease may alert the surgeon to the correct diagnosis.

SURGERY FOR DIVERTICULAR DISEASE

Small multiple diverticula are a common incidental finding in the sigmoid colon, although diverticula may extend more proximally. Surgery is usually only indicated for patients who develop complications. The symptoms and complications of diverticular disease in the Western world are almost entirely confined to the sigmoid colon, and only the sigmoid colon needs be excised, even when the diverticular process is extensive.

ELECTIVE RESECTION

An elective resection may be undertaken for repeated attacks of diverticulitis, for a diverticular stricture or for chronic low-grade symptoms. A *sigmoid colectomy* is the standard operation in the elective setting, and this is described in Chapter 14. In open surgery, a left iliac fossa muscle-cutting incision provides adequate access, but it cannot be extended upwards as easily as a midline incision if more extensive access becomes necessary. The level of the proximal resection is chosen so that the colon reaches easily to the top of the rectum for an anastomosis. The proximal resection margin should be above any narrow, thickened sigmoid, but it does not need to be above all diverticula. A division at the level of the proximal sigmoid colon, or lower descending colon, is usually suitable. The superior rectal artery can be preserved and the sigmoid branches divided, as a radical lymphadenectomy is not necessary for benign disease. The distal resection is at the level where the taeniae have spread out to form a continuous muscle coat (Figure 13.15). Division at a more proximal level results in a high incidence of recurrent problems. A hand-sewn anastomosis just below the pelvic brim is often easier than a stapled one, as the stapling gun may not pass easily up through the folds of the non-mobilised rectum. If the anastomosis is deeper into the pelvis, a stapled anastomosis will be easier.



13.15 The anastomosis after a sigmoid colectomy for diverticular disease must be to rectum distal to the high-pressure zone of the rectosigmoid junction. The surgical landmark is the spreading of the taeniae to form a continuous longitudinal muscle coat. ⏎

Unfortunately, even in the elective situation, this classical sigmoid colectomy may not be possible. A shortened, thickened sigmoid colon and mesentery may make preservation of the superior rectal artery impossible, and the descending colon may not reach for a tension-free anastomosis without full mobilisation of the splenic flexure. Occasionally, the proximal diverticula are so extensive that there is no suitable distal descending colon free of diverticula for a safe anastomosis, and a more proximal level for the transection is necessary. The surgeon must therefore be prepared to carry out a left hemicolectomy rather than a sigmoid colectomy if this is more appropriate.

Many surgeons prefer a left hemicolectomy as their standard procedure for sigmoid diverticular disease. They propose that this avoids the problems outlined above and that a left hemicolectomy is a more anatomical dissection. Additionally a left hemicolectomy is oncologically superior if an unsuspected cancer is present within the diverticular segment. A more radical removal of more of the diverticula may also improve the long-term outcome of surgery. In addition, straightening of the colon makes any subsequent endoscopic imaging less difficult. Unfortunately, a left hemicolectomy is a more major procedure, requires the incision to be extended higher, with a greater risk of postoperative respiratory complications, and splenic flexure mobilisation may result in loss of the spleen as a result of iatrogenic trauma.

The dissection may also have to be carried down into the pelvis if the sigmoid loop is folded over and adherent. Dense adherence to the front of the rectum is best managed by converting the operation into an anterior resection. Dense adhesions to the bladder, uterus or vaginal vault can be pinched off by blunt dissection. If there is a fistulous opening into the dome of the bladder, or into the vagina, the fistula is repaired. For both bladder and vagina, dissolvable sutures are mandatory and, as both organs are very vascular, a continuous haemostatic suture is recommended with a second layer of interrupted sutures. It is advantageous to position the patient in the ‘legs-up’ position in anticipation of these problems, as it allows an assistant to retract from between the legs during any pelvic dissection. In addition, the anus is exposed should a stapled anastomosis be needed.

URGENT SURGERY

A more urgent operation may be necessary for an attack of acute diverticulitis that fails to resolve on medical treatment. Occasionally, surgery can be deferred if image-guided drainage of a pericolic abscess can be performed, after which the antibiotics are effective in treating the remaining infection. Surgery also has to be expedited in patients who develop a frank colovaginal fistula or colovesical fistula. The operative conditions are worse during an active episode of inflammation than in the elective situation. The bowel is often partially obstructed and there is more likely to be doubt as to whether the underlying pathology is cancer or diverticular disease. The tissues are inflamed and friable and a pericolic abscess is common. The resection is similar to that in the elective case, but it may be technically more difficult. An anastomosis to restore continuity can usually be recommended, but consideration should be given to the advisability of protecting the anastomosis with a temporary proximal loop stoma.

EMERGENCY SURGERY

Emergency surgery will be necessary if there is generalised purulent peritonitis from rupture of a pericolic abscess or a feculent peritonitis from rupture of the inflamed sigmoid colon. Less commonly, emergency surgery is necessary for a diverticular obstruction or haemorrhage, both of which can occur in the absence of an acute inflammatory episode. Surgery of these latter two complications was discussed earlier in the chapter.

Emergency surgery for perforated diverticular disease carries a high mortality rate. Despite the poor condition of many of these patients when they come to surgery, a resection should be performed, as drainage of the peritoneal cavity, combined with a defunctioning proximal stoma, has generally been shown to be associated with a worse outcome. Unless there is gross faecal soiling of the peritoneum, or the patient is so unwell that the operation cannot be safely prolonged, an anastomosis is recommended but should generally be defunctioned by a proximal loop stoma. This can be closed at a relatively minor second operation after 3–6 months.

When an anastomosis is contraindicated, a Hartmann's procedure is undertaken. The rectal stump is closed and marked with a nylon suture to make subsequent identification easier, and the proximal bowel end is brought out as an end stoma. Some surgeons recommend dividing the distal end more proximally, so that the bowel can be brought out at the lower end of the wound as a mucous fistula to make the subsequent dissection for a rejoin easier. However, this is seldom a satisfactory solution, even when it is technically possible. A segment of distal sigmoid colon affected by diverticular disease has been retained and must be resected at the subsequent operation before bowel continuity can be restored. In addition, if the inferior mesenteric artery has been ligated, this distal colon brought out as a mucous fistula may be ischaemic.

A relatively mild diverticulitis is occasionally encountered at operation for a suspected appendicitis. The decision on whether to proceed to a resection or to close the abdomen, with or without a left iliac fossa drain, and treat conservatively will depend on the findings and circumstances.

Differential diagnosis of sigmoid diverticular disease and sigmoid malignancy

Unfortunately, even at the start of an elective operation, preoperative endoscopy, rectal contrast studies and sophisticated imaging may have failed to elucidate whether the sigmoid pathology is diverticular disease or a cancer. Confirmation of the diagnosis by preoperative endoscopic biopsy is often frustrated by the angulation and fixity of the sigmoid loop. Paediatric endoscopes, and brush biopsy techniques, will shed further light in some patients, but are not always successful. CT and magnetic resonance imaging scans provide preoperative evidence of the 'invasion' of other organs, but they cannot always differentiate between tumour invasion and the inflammatory involvement of adjacent tissue. If doubt remains after the abdomen is opened, and a sigmoid mass adherent to other organs is encountered, the surgery must be radical to prevent rupture into tumour planes. This requires not only a radical lymphadenectomy but also excision of the adherent disc of any other organ involved in the diseased process. When this can only be achieved by an extended radical dissection, it is immediately apparent how important it was to have made every effort to differentiate between the two pathologies preoperatively.

Solitary giant diverticulum

A solitary giant diverticulum may occur anywhere throughout the colon, and excision is usually indicated. A caecal diverticulum with an inflammatory mass around it can mimic a caecal carcinoma. However, difficulties in differentiating a caecal inflammatory mass from a caecal malignancy are less common than the diagnostic difficulties in the sigmoid colon.

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14 Operative management of small and large bowel malignancy

Brendan Moran, Amy Lord and Rohin Mittal

The surgery of small and large bowel malignancy forms a large proportion of the workload of a gastrointestinal surgeon. Almost without exception, the only single intervention that can offer a patient the chance of a cure is a well-performed operative resection, with the addition of neoadjuvant (preoperative) radiotherapy and/or chemotherapy in selected cases, particularly patients with advanced rectal cancer. However, the need for a laparotomy to establish whether potentially curative surgery is possible has diminished with improvements in preoperative imaging, and palliative interventions may be performed by radiologists, radiotherapists and oncologists, in addition to occasional palliative surgical procedures. When a curative resection is possible, it is of the utmost importance that a surgeon does not jeopardise the possibility of cure by inadequate or poorly planned surgery. When cure is no longer possible, radical surgery sometimes still offers the best palliation, but the surgeon must avoid inappropriate radical surgery. A simpler operative procedure may be as effective in relieving symptoms and, in other situations, surgery may have no place. Surgeons must understand the methods of spread and the natural history of the various intra-abdominal malignancies if they are to make the best operative decisions.

COLORECTAL CANCER

Colorectal cancer is one of the most common malignancies worldwide. Patients generally present with an alteration in bowel habit, rectal bleeding or iron-deficiency anaemia. Increasingly, however, colorectal cancer is being diagnosed through bowel cancer screening programmes, which offer the potential advantage of earlier diagnosis at a curable stage of the disease. Most diagnoses are made at colonoscopy but there is an increasing use of computed tomography (CT) colonography, particularly in older patients or those with coexisting morbidities, for whom colonoscopy may be deemed inappropriate. The disadvantage of CT colonography is that endoscopic biopsy may be subsequently needed in order to confirm a tissue diagnosis of adenocarcinoma. Diagnosis of colorectal cancer relies on endoscopic appearance and biopsy results and a CT scan of the chest, abdomen and pelvis is recommended to both assess local tumour staging and look for distant metastatic disease at baseline. For rectal cancer, a magnetic resonance imaging (MRI) scan of the rectum is strongly recommended, as this adds important information about local staging, including the presence of extramural tumour spread and the predicted safety of the circumferential resection margin, which will determine treatment strategy. All patients with colorectal cancer should be discussed in a multidisciplinary meeting, where feasible, to determine optimal management.

In the absence of metastatic disease or inoperable invasion into adjacent structures, the majority of patients with colonic cancer will be treated primarily with surgery. Chemotherapy or immunotherapy may have a role to play in the neoadjuvant (pre-surgery) setting, but is not standard practice at present in patients with operable disease. Patients who are found to have more advanced tumours on pathology (e.g. T4 tumours and those with involved lymph nodes or extramural venous invasion on the resected specimen) may be offered adjuvant chemotherapy to reduce their risk of relapse.

Preoperative staging of the local extent of the tumour is of the greatest relevance in patients with rectal cancer in whom even a pathological stage T3 N0 tumour can threaten the planes of excision (Figure 14.1). Neoadjuvant (preoperative) radiotherapy, chemotherapy and chemoradiotherapy all have a role to play in the treatment of rectal cancer, and their selective use improves results.

Neoadjuvant treatment options are constantly evolving, and a discussion of the choice between different treatments is beyond the scope of this book. Options include short-course radiotherapy, long-course chemoradiotherapy and total neoadjuvant

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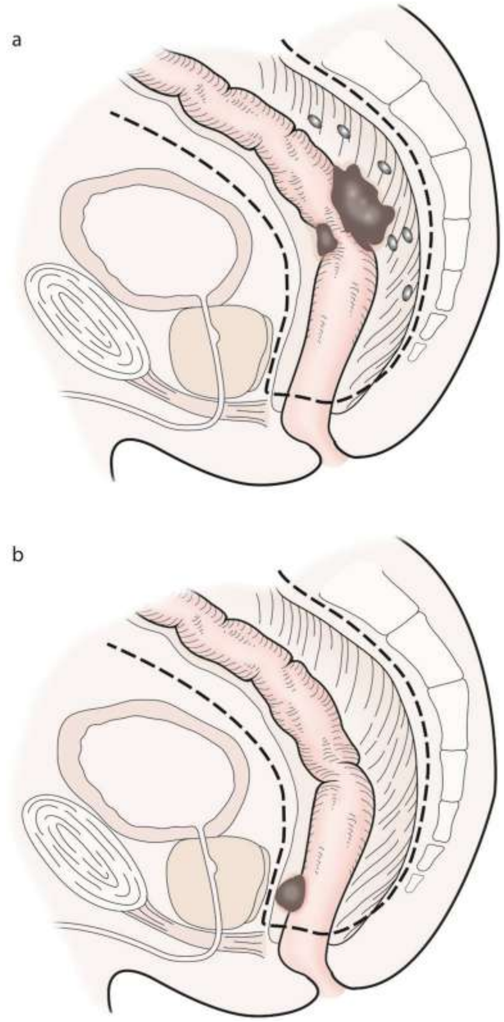


14.1 Staging of rectal cancer by MRI scanning is valuable for showing the relationship of the tumour to the planes for excision. (a) A large tumour, which is invading for several centimetres into the posterior mesorectum. There are enlarged nodes, which probably contain metastases. (b) A smaller, earlier tumour that extends only a few millimetres into the thin anterior mesorectum. There is no evidence of nodal involvement. Despite the more advanced staging of the tumour in (a) than that in the tumour in (b), the excision margin on the mesorectal fascia, shown as a dotted line, is well clear of tumour in (a) but closer in (b). ⏎

therapy. Short-course radiotherapy involves administering a total of 25 Gy radiotherapy (5 Gy daily for 5 days), with surgery within 1 week of completion, which can 'sterilise' the tumour periphery (peripheral edges of the cancer); in historic trials, this was shown to reduce the incidence of pelvic recurrence. At operation, within a week of completion of short-course radiotherapy, the size of the tumour is unchanged and, provided the surgery is carried out without delay, the dissection planes are not fibrosed. However, late radiotherapy morbidity is at least equivalent to that after the standard long-course regimen. In the modern era of accurate MRI staging and oncological improvements in surgical technique, the benefit of short-course radiotherapy is not clear, but some surgeons advocate its use selectively for patients at higher risk of local recurrence.[1]

A long course of radiotherapy comprising 45–50 Gy over 6 weeks will usually shrink ('downsize') and 'downstage' an advanced tumour and thus makes many tumours resectable that were initially fixed to adjacent structures. Increasingly, this is combined with neoadjuvant chemotherapy. A delay of 8–12 weeks after completion of the radiotherapy allows for maximum shrinkage of the tumour. Radiotherapy also kills the cells at the periphery of the remaining tumour mass and reduces the likelihood of implantation of viable tumour cells in the event of the dissection entering a 'tumour plane'. The surgeon will be aware during the dissection that the planes are more difficult to follow due to radiotherapy changes, and there can also be difficulty in deciding what margins of resection are needed, especially if the tumour has regressed substantially.

In recent years, there has been an increase in popularity of total neoadjuvant therapy (TNT), which refers to giving additional chemotherapy preoperatively such that the patient receives all of their oncological treatment 'up front'. There are various different protocols that vary in terms of the chemotherapy agents used and the order in which treatments are given. There is still insufficient evidence as to which patients benefit most from each treatment strategy, and this has led to a widespread variation in treatment guidelines. Indeed, the treatment that two patients with the same stage of tumour would be offered can differ between different hospitals, regions and countries.

Both radiotherapy and chemotherapy have the potential to increase the risk of anastomotic leakage after an anterior resection. Both also impair perineal healing after an abdominoperineal resection to the extent that a myocutaneous flap reconstruction should be considered.[2] Radiotherapy is a major risk factor for low anterior resection syndrome (LARS), the term for an impairment in bowel function after rectal cancer surgery, and is also associated with an increased incidence of sexual and bladder dysfunction. When surgery is delayed for neoadjuvant treatment, a defunctioning stoma is often beneficial, as symptoms from the tumour may intensify during treatment.

There are three areas in rectal cancer management where decisions are complex and where 'decisions are more important than incisions'.[3] These three scenarios are in patients with locally advanced rectal tumours, patients at the other end of the spectrum with superficial cancers and those with unstable colonic mucosa, for example where there is a background of inflammatory bowel disease.

RADICAL COLON RESECTIONS

Adenocarcinoma of the colon is a malignancy that, at presentation, often has lymph node involvement in the absence of distant metastases. It is, therefore, still potentially curable if the primary tumour is excised *en bloc* with its lymphatic drainage. As the lymphatic drainage follows the arterial supply, radical lymphadenectomy is planned on the arterial anatomy of the colonic mesentery (see Figure 13.2). The ascending and descending colon and the rectum have retroperitoneal mesenteries, and large bowel resections are therefore predominantly concerned with accurate dissection to isolate these mesenteries.

The length of bowel to be excised is determined by considerations of reconstruction. The ends must reach for a tension-free anastomosis with an adequate blood supply for healing. Radical lymphadenectomy inevitably compromises the vascularity of a longer segment of bowel than that which would have to be excised to clear a tumour, which has minimal ability to spread intramurally. The extent of the lymphadenectomy is thus the important determinant of the length of colon that has to be excised.

The anastomosis after a large bowel resection may be more technically challenging than a small bowel anastomosis because of poor access, but the same general anastomotic principles apply. The blood supply is more critical in the colon than in the small bowel, and is one reason why anastomoses are more vulnerable. Solid intraluminal material with a high bacterial content is an additional adverse factor. An ileocolic anastomosis is safer than an anastomosis of colon to colon, and a coloanal anastomosis is the most vulnerable of all. Preoperative mechanical emptying of the colon (except in obstruction) and the use of preoperative oral antibiotics have been shown in some trials to reduce the risk of surgical site infection and anastomotic leak, but the evidence is conflicting and the topic remains controversial.[4] Perioperative antibiotics should be given to reduce septic complications in all colonic resections (see Chapter 3).

Radical colonic resections can be undertaken either by the classical open approaches or laparoscopically. Any short-term benefit of the latter method in terms of a faster postoperative recovery is obviously negated if the surgeon is unable to offer an equally secure anastomosis after an equally precise and radical removal of the malignancy. The choice of method will depend on factors such as the position of the tumour, the build of the patient, the relative skills of the surgeon in the two methods and the availability of laparoscopic equipment. A small tumour can be difficult to locate at laparoscopy and, if laparoscopic surgery is planned, then the colon should have been tattooed 5 cm distal to the tumour at endoscopy.

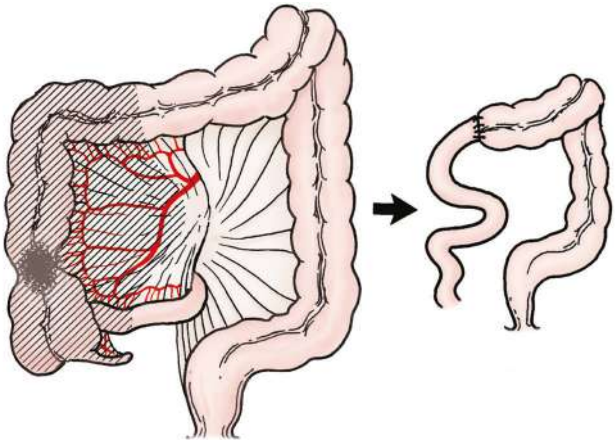
The operations all commence with an assessment of the primary tumour and a general exploration for previously undetected tumour spread or other pathology. Every operation must then be tailored to the vascular anatomy and the length and mobility of the colon in the individual patient. The exact position of the tumour may dictate adaptations of a standard resection. A more radical excision may be justified for a locally advanced but still potentially curable tumour, and loops of adherent small bowel, or other organs, may have to be excised *en bloc*. Conversely, a less radical lymphadenectomy may be a justifiable alternative in the presence of inoperable liver secondaries or in a frail older patient. In these instances, the primary lesion can be excised with only a limited wedge of mesentery, thus minimising the dissection for mobilisation. All modified resections are, however, based on the standard resections described below.

RIGHT HEMICOLECTOMY

A radical right hemicolectomy is performed for malignant tumours of the caecum, ascending colon and hepatic flexure, and also for the less common malignant tumours of the appendix or terminal ileum. Radical lymphadenectomy involves the excision of the lymphatic drainage from the tumour to the proximal mesenteric nodes, which are around the origin of the ileocolic and right colic arteries from the superior mesenteric artery. Ligation of these arteries at their origin determines the length of colon to be excised (Figure 14.2). The right colon must be mobilised with its retroperitoneal 'mesentery' from the right paracolic gutter, as described in Chapter 7. The white line on the peritoneum lateral to the right colon is a guide for entering the plane between this mesentery and the truly retroperitoneal structures.

Open right hemicolectomy

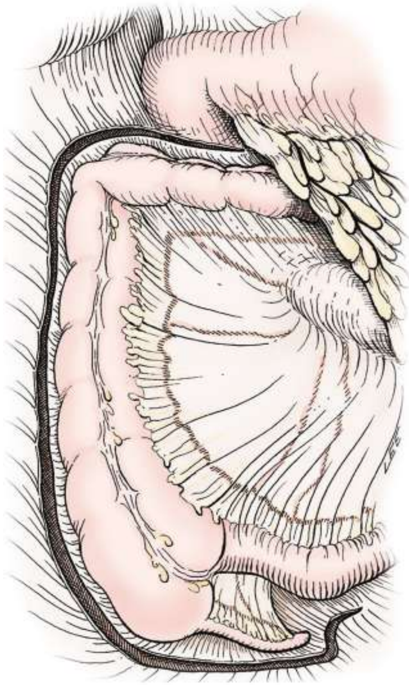
Most surgeons favour a midline incision. Good intraperitoneal access is obtained by retraction and small bowel exclusion from the operative field (see Chapter 7). The peritoneum is incised along the white line lateral to the right colon and extended as shown in Figure 14.3. The areolar plane is identified by retraction of the ascending colon forwards and medially. This avascular plane behind the colon is followed medially by sharp dissection, allowing the gonadal vessels and ureter to fall back into place. An injured gonadal vessel may have to be ligated; generally, no adverse effects on the testis result from ligation within the abdomen. The ureter must be identified and



14.2 A right hemicolectomy. The right colic and ileocolic vessels are divided and the tumour is excised en bloc with the lymphatic drainage alongside these arteries. The bowel supplied by these arteries is excised and continuity is restored by an ileocolic anastomosis to the proximal transverse colon. A right hemicolectomy for a caecal pole tumour should include in the resection specimen the lymphatic channels alongside the terminal arcade of the mesenteric root; a longer segment of terminal ileum may have to be sacrificed. ⏎

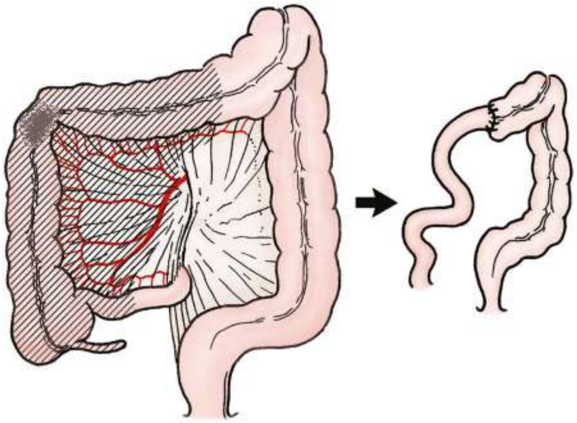
protected from injury. Inadvertent ureteric injury or the need to sacrifice a ureter on oncological grounds is discussed in Chapter 25. As the dissection is continued medially, the second part of the duodenum and the anterior surface of the head of the pancreas are exposed, and care must be taken to prevent tears to small delicate vessels in this area. If bleeding does occur, it is best treated initially by the application of an adrenaline-soaked swab, which is left undisturbed for 5 minutes. Continuing bleeding should be controlled by a fine suture, as the application of artery forceps or diathermy may cause further pancreatic trauma. The superior mesenteric artery and vein are identifiable just below the pancreas, at the root of the mesentery.

The line of the mesenteric transection is lateral to the main trunks of the superior mesenteric vessels, which must be preserved. The ileocaecal valve, 15–25 cm of terminal ileum and the ileocolic vascular arcade with the associated lymphatic drainage are included in the resected specimen. The superior mesenteric, right colic and ileocolic arteries are often visible in the mobilised mesentery but, if not, their position can be confirmed by palpation. The ileocolic and right colic arteries are ligated and divided close to their origin, but with care being taken to avoid damage to the superior mesenteric vein, which usually lies along the right side of the superior mesenteric artery throughout this dissection. An elegant dissection (now often referred to as a 'central vascular ligation' as part of a 'complete mesocolic excision' procedure), which guarantees a radical lymphadenectomy, involves the initial identification and exposure of the distal superior mesenteric vessels. The dissection is then carried proximally along the right lateral surface of the superior mesenteric vein, exposing the vein along its length. The ileocolic and right colic vessels are ligated. The dissection can be carried to the origin of the middle colic vessels for a tumour of the hepatic flexure. Finally, the mesenteric division is extended to the ileum and the transverse mesocolon, at the sites chosen for the division of the bowel. The ileocolic anastomosis may then be constructed end-to-end or side-to-side, either with hand sutures or with a stapling device (see Chapter 7).

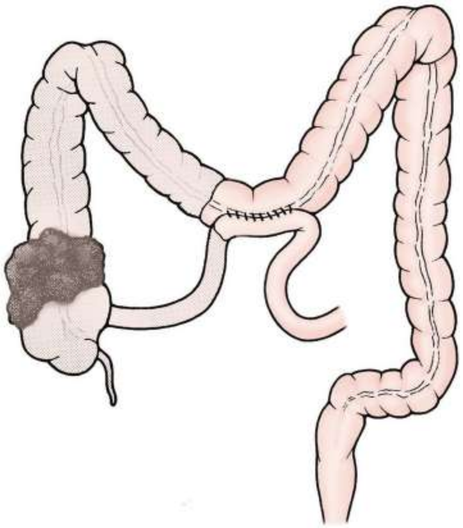


14.3 In an open right hemicolectomy, the lateral peritoneal incision is the first step in mobilising the right colon with its retroperitoneal mesentery. Note the relationship to the second part of the duodenum. ⏎

Variations Some surgeons prefer to ligate the vascular pedicle before mobilising the right colon, which is then mobilised in a retrograde direction. If the tumour is at the hepatic flexure, lymphatic drainage alongside the right branch of the middle colic must be included in the resection (Figure 14.4) and the right half of the greater omentum should be removed with the specimen, with no attempt made to separate it from the colon (see Figure 14.7). If the tumour is in the caecum, a longer segment of terminal ileum should be removed if the tumour appears to be draining along the terminal arcade of the superior mesenteric artery (see Figure 14.2).



14.4 A right hemicolectomy for a tumour at the hepatic flexure should include in the resection specimen the lymphatic channels alongside the right branch of the middle colic artery. ⏎



14.5 An ileocolic bypass will relieve the obstruction from a right-sided colonic tumour, but resection of the primary tumour offers better palliation, even in the presence of metastatic disease. ⏎

A tumour that is adherent to the anterolateral abdominal wall should be excised with the adherent disc of peritoneum and abdominal wall muscle. Similarly, an adherent loop of small bowel should be excised with the specimen. Posterior invasion may necessitate excision of part of the ureter or a disc of duodenum, but the surgeon must evaluate carefully whether this will remove all palpable tumour. If all the tumour cannot be removed, an ileocolic bypass will almost certainly be a wiser palliative procedure (Figure 14.5). A mobile tumour, however, is better resected than bypassed, even if there are inoperable secondaries in the para-aortic nodes or liver, as a tumour left *in situ* may continue to bleed and small bowel loops may become involved and obstruct.

Laparoscopic right hemicolectomy

A Lloyd-Davies position allows the surgeon, or an assistant, to stand between the legs of the patient. The leg supports also help to prevent the patient from slipping when steep Trendelenburg or reverse Trendelenburg positions are needed to help retract the small bowel, but shoulder supports should be used as well. An umbilical camera port is used, and three further ports are established on the left side of the abdomen. A 12 mm port in the left iliac fossa, through which a stapler can be passed if necessary, and two 5 mm ports, one suprapubically and the other in the left upper quadrant for use by an assistant, form a satisfactory arrangement. The exact position of the ports will depend on the preference of the individual surgeon and the underlying pathology. The dissection is usually started medially with the ileocolic pedicle. The small bowel is moved into the left side of the abdomen so that the mesentery of the caecum and ascending colon is uncovered. This mesentery is then grasped close to the caecum and retracted laterally and towards the anterior abdominal wall. The ileocolic pedicle is thus placed under tension and is visible as a tented fold in the mesentery.

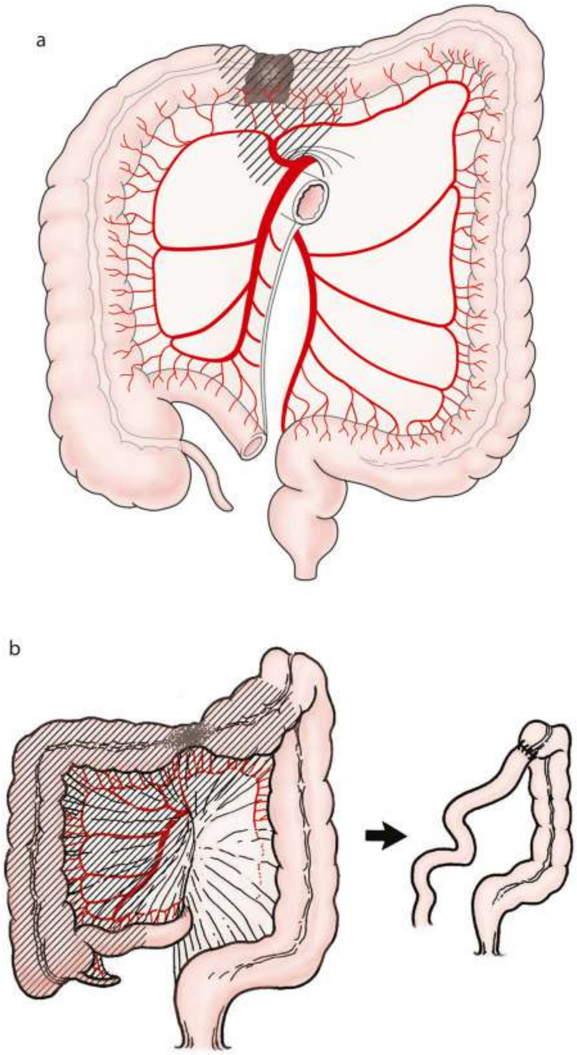
Dissection starts by dividing the peritoneum immediately below the ileocolic vessel to enter the retroperitoneal plane behind the mesentery. This plane is then developed superiorly, and laterally, by precise blunt dissection. When followed correctly, this plane is bloodless, even without using any coagulation, and excessive bleeding usually indicates the wrong plane has been entered. The duodenum will be identified medially and is pushed gently posteriorly away from the mesentery. Once the dissection has passed behind the ileocolic pedicle, a window can be made through the mesentery to allow division of the pedicle with a vascular laparoscopic stapler. The right colic vessels are dealt with in a similar fashion. Clips are a cheaper alternative to a stapler, but require more dissection to skeletonise the vessel before clips can be applied.

The retroperitoneal plane can then be followed superiorly over the curve of the duodenum and the pancreatic head and laterally behind the colon as far as the abdominal sidewall. The mobilisation of the colon is then completed by dividing the peritoneum laterally along the white line. Where a bulky caecal tumour distorts the anatomy around the ileocolic pedicle, a lateral to medial dissection may be carried out in the same fashion as for the open operation, but the view is often more limited.

As an incision is required to deliver the tumour, the final dissection of small bowel mesentery, the omentum up to the resection margins on the bowel and, finally, the anastomosis itself may be carried out as an open procedure after delivery of the specimen. A small midline or transverse right-sided incision is made and the edges of this incision are protected by a plastic wound protector to reduce the risk of seeding tumour cells into the wound. If a bulky tumour or colon cannot be easily delivered, the wound should be enlarged to avoid the risk of perforating the tumour during aggressive attempts at delivery. Anastomosis is then carried out as for an open operation, and the abdomen is closed.

TRANSVERSE COLECTOMY

There are often several alternative strategies for a cancer in the transverse colon. A radical lymphadenectomy is the fundamental consideration, and this is planned on the basis of the arterial supply. This will then dictate the segment of bowel that must be excised and the mobilisation necessary to bring the ends together for the anastomosis. A transverse colectomy is occasionally appropriate for a tumour near the apex of a long transverse colon. The vascular pedicle, with the associated lymphatic vessels, is the middle colic artery, and minimal dissection is required (Figure 14.6a). The drawback is a colocolic anastomosis using the area proximal to the splenic flexure, where blood supply may be marginal. Many surgeons therefore prefer to perform an extended right hemicolectomy for tumours of the transverse colon, and the well-vascularised terminal ileum is then used for a safer ileocolic anastomosis (Figure 14.6b). A more major dissection is offset by a more reliable anastomosis. In either operation, the middle colic pedicle is ligated at its origin, and the greater omentum removed with the specimen after separation of the greater omentum from the stomach by multiple ligations of gastroepiploic vessels (Figure 14.7).

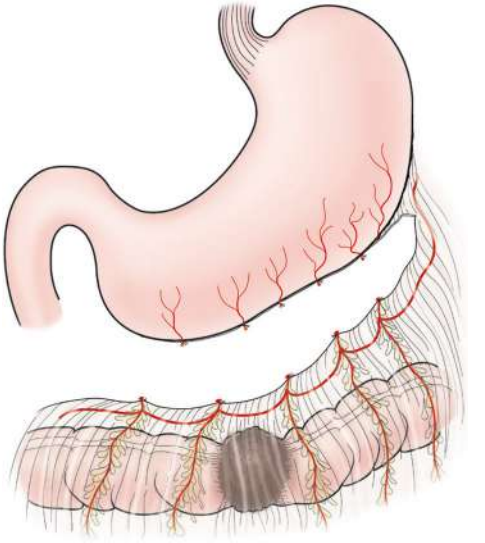


14.6 In the resection of a transverse colon cancer, the surgeon has two main options. (a) A transverse colectomy with a radical lymphadenectomy based on the middle colic artery is a good oncological resection. It is suitable for patients with a long transverse colon and a good marginal artery around the splenic flexure. (b) An extended right hemicolectomy is preferred by many surgeons. The resection specimen should still include the lymphatic channels alongside the middle colic artery. ⏎

EXTENDED RIGHT HEMICOLECTOMY

An extended right hemicolectomy is an alternative resection to a transverse colectomy for a transverse colon cancer; the colonic resection can be further extended to make it an alternative to a left hemicolectomy for a cancer of the splenic flexure or descending colon.

If an extended right hemicolectomy is performed for a cancer in the transverse colon, it must



14.7 The omentum should be excised en bloc with a tumour of the transverse colon. No attempt is made to separate the omentum from the colon; instead, it is freed from the greater curve of the stomach by multiple ligations of gastroepiploic vessels. ⏎

be remembered that the lymphatic drainage of the tumour will be alongside the middle colic artery, and it is this vessel that should be divided near its origin. Similarly, when an extended right hemicolectomy is performed for tumours at, or below, the splenic flexure, the lymphatic drainage alongside the ascending left colic artery is the most important, and this is the vessel that should be divided at its origin to secure a radical lymphadenectomy (see Figure 14.6). The level at which the right colic vessels are divided is not important.

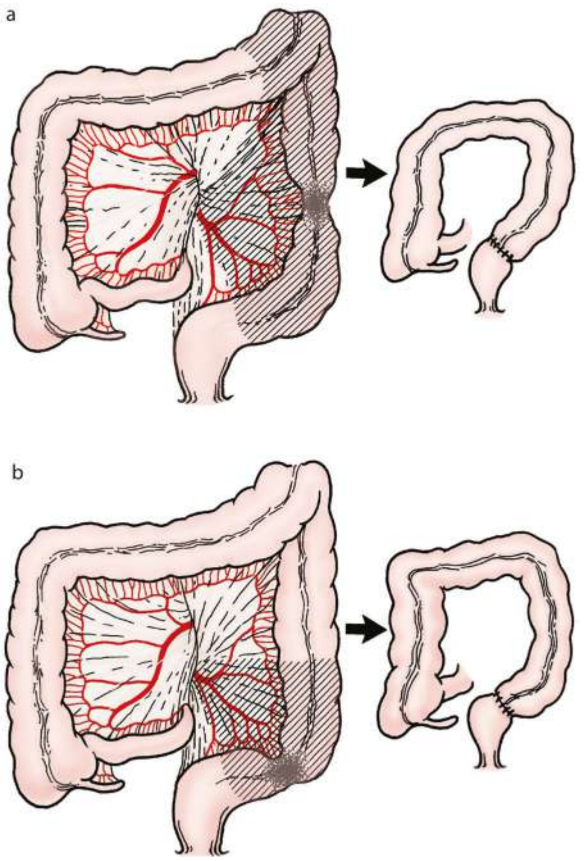
Laparoscopic dissection is the same, in principle, as for an open extended right hemicolectomy. The right colonic mobilisation is carried out with a medial to lateral dissection. Good retraction of the transverse colon can be difficult laparoscopically, resulting in a lengthy dissection. It is often easier to carry out the bulk of the dissection laparoscopically, but to take the middle colic vessels via the same short midline incision used to retrieve the specimen.

LEFT HEMICOLECTOMY

This is the standard operation for colonic tumours in the colon supplied by the inferior mesenteric artery (Figure 14.8). An anterior resection of the rectum is an extension of the basic left hemicolectomy. The inferior mesenteric artery is ligated close to its origin from the aorta and the lymphadenectomy thus extends to the mesenteric root. The extent of the colonic excision is shown in Figure 14.8a. The rectum below the peritoneal reflection has an adequate blood supply from below. The marginal artery allows preservation of the descending colon and, variably, of the sigmoid. It may, therefore, be possible with distal tumours to excise only the sigmoid colon (Figure 14.8b). In all situations, however, great care must be taken to perform a radical excision of the lymph nodes and lymphatic channels in the line of drainage of the tumour. Incisions or tears into the 'mesentery' are into potentially malignant channels, and thus jeopardise cure. There is a choice of an open or laparoscopic approach for a left hemicolectomy.

Open left hemicolectomy

A Lloyd-Davies position (see Figure 15.3a) is advantageous, as this allows the surgeon to stand between the legs for optimal access when releasing the splenic flexure. In addition, retraction from this position is useful if pelvic dissection is required. In addition, if the anastomosis has to be lower than anticipated, and access is difficult for a hand-sewn anastomosis, a circular mechanical stapler can be inserted *per anum*.

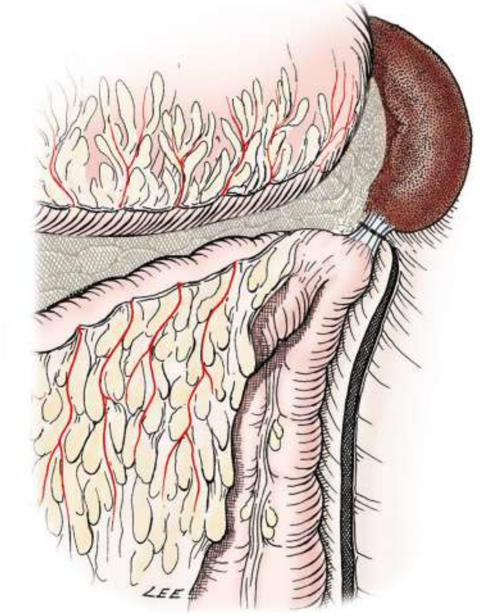


14.8 A left hemicolectomy is based on the lymphatic drainage around the inferior mesenteric artery. (a) The whole left colon with the exception of the rectum has been excised. (b) Even after a high ligation of the inferior mesenteric artery, a good marginal artery may be sufficient to allow retention of the whole descending and proximal sigmoid colon. ⏎

A midline incision allows better access for splenic flexure mobilisation and high ligation of the inferior mesenteric artery than the alternative oblique left iliac fossa incision. The principles of mobilisation of the left colon are similar to those of the right colon. Before the lateral peritoneum is divided, it may be necessary to divide adhesions between the sigmoid colon and the anterolateral abdominal wall or pelvic organs. These peritoneal adhesions may be congenital, but more often they are inflammatory or postoperative adhesions, for example following previous gynaecological surgery. If, however, the tumour is in the sigmoid colon, and these adhesions are dense, they may represent local malignant infiltration. The resection must therefore be more radical in order to prevent rupturing the tumour. An ovary, a disc of abdominal wall muscle or part of the dome of the bladder may have to be excised *en bloc* with the tumour. A sigmoid tumour may be folded down into the pelvis with malignant adhesions to the anterior rectal wall. In this situation, an anterior resection will be necessary for a tumour that was as high as 30 or 40 cm from the anal verge at endoscopy.

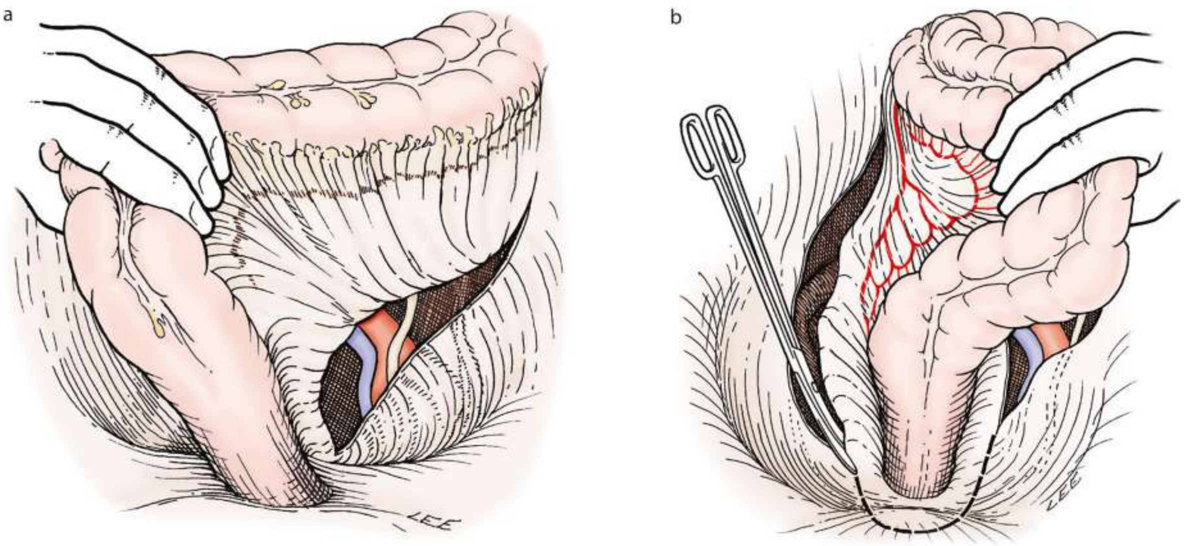
Left colon mobilisation is then continued by incision of the peritoneum lateral to the distal descending colon (Figure 14.9) and the plane entered behind the retroperitoneal ‘mesentery’. Lateral mobilisation of the descending colon is continued up towards, and finally around, the splenic flexure. It is easy at this stage to damage the spleen. Damage is most commonly caused through tearing an omental adhesion off the lower pole of the spleen by excessive retraction on the colon or, more frequently, on the omentum. Good access is essential for a difficult mobilisation of a high splenic flexure, and there should be no reluctance to extend the wound. A high splenic flexure is best approached from both sides. The plane between the transverse colon and the greater omentum is opened and followed laterally towards the flexure. This manoeuvre allows the omentum to be retracted anteriorly, releasing any tension on adhesions between the omentum and the spleen, and guides the dissection into the correct plane. With gentle traction on the colon, the peritoneum is divided around the flexure. If visualisation is still poor, a finger inserted under the peritoneum, to draw down and protect the colon, is also helpful in displaying the final strands to be divided (Figure 14.9). A splenic flexure tumour will require the left side of the omentum to be excised *en bloc* with the specimen. The greater omentum is then not separated from the colon, but instead is separated from the stomach by division of the gastro-epiploic vessels, as shown in Figure 14.7. The spleen may have to be excised with the specimen in a locally advanced splenic flexure tumour. In addition, it can be damaged inadvertently during splenic flexure mobilisation. A damaged spleen can sometimes be saved, but unfortunately a splenectomy is often required (see Chapter 11). Once the splenic flexure has been fully released, it can be lifted forwards and medially and its ‘mesentery’ released from the underlying pancreas and duodenojejunal flexure.

Mobilisation of the descending and sigmoid colon is continued medially by following the areolar plane between mesenteric structures anteriorly and gonadal vessels and ureter posteriorly. A damaged gonadal vessel can be sacrificed, but the ureter should be identified early in this dissection and carefully preserved (Figure 14.10a). The ureter is occasionally involved in a tumour and has to be resected (see Chapter 25). If preoperative imaging suggests that the tumour may be close to locally advanced disease, then elective stenting of the ureter at the start of the operation may be helpful. When the dissection has reached the midline, it is helpful to insert a swab into the extremity of the dissection before turning the colon back to the left, and making a peritoneal incision, posteriorly on the right of the sigmoid mesentery (Figure 14.10b). The swab is visible immediately on dividing the peritoneum and aids identification of the window behind the inferior mesenteric artery, but in front of the hypogastric nerve plexus on the surface of the aorta. This plane is then followed up until the origin of the inferior mesenteric artery can be felt between finger and thumb. The artery and the vein are clamped, ligated and divided separately; many surgeons prefer a transfixion ligation for the artery. Care should be taken to preserve the sympathetic nerve fibres on the anterior surface of the aorta and, for this reason, ligation of the inferior mesenteric artery 1–2 cm from its origin is preferable to a flush tie on the aorta. As the artery is skeletonised prior to clamping, the fat and lymphatic tissue of the proximal centimetre of mesentery can be drawn into the specimen.



14.9 Left colon mobilisation commences with an incision of the peritoneum lateral to the distal descending colon. Above the transverse colon, the greater omentum has been separated from the stomach by division of epiploic vessels. (Except for splenic flexure tumours, the alternative plane between the transverse colon and the omentum is preferable.) A finger introduced along the distal transverse colon and around the flexure, deep to the remaining peritoneum that is tethering it, will define the remaining tissue to be divided and protect the colon from injury. Excessive traction on the colon may tear adhesions off the spleen and damage it. ⏎

At this stage, a ‘division of convenience’ of the colon improves access for the final dissection. Division with a mechanical stapler or between small crushing clamps is suitable. It is important not to divide the colon too proximally, remembering that excessive length can be trimmed but colon that will not reach the rectum may pose a major challenge to a restorative anastomosis. The mesentery is then divided between the inferior mesenteric root and the colonic division.



14.10 A left hemicolectomy. (a) The descending and sigmoid colon mobilisation starts on the left, and the ureter must be identified early. (b) When the dissection from the left has reached the midline, the colon is swung to the left. The right leaf of the peritoneum is incised to form a window in front of the aorta and behind the mesenteric package, which contains the inferior mesenteric artery, its branches and the lymphatic drainage of the hind gut. The inferior mesenteric artery is then ligated and divided close to its origin. The anterior and lateral peritoneal incisions around the rectum allow it to be drawn up to make an anastomosis easier. ⏎

The sigmoid colon can now be retracted anteriorly to display the continuation of the posterior areolar plane over the pelvic brim and into the pelvis behind the mesorectum. The autonomic nerves lying on the aorta and the posterior pelvic brim should be carefully preserved. Only minimal dissection is required in the pelvis and is employed simply to gain rectal mobility for the anastomosis. Division of the peritoneum, lateral and anterior to the rectum, will also allow further upwards mobilisation of the rectum (Figure 14.10b). The level of the distal resection site is finalised. This should be below the pelvic brim and not more than a few centimetres above the peritoneal reflection. A higher division carries a risk of inadequate perfusion of the distal end of the anastomosis. The mesentery posteriorly is divided between forceps and ligated. A right-angled clamp is placed across the bowel to prevent contamination from above, and the bowel is divided. The rectum is emptied by suction and liberally washed with a tumouricidal solution.

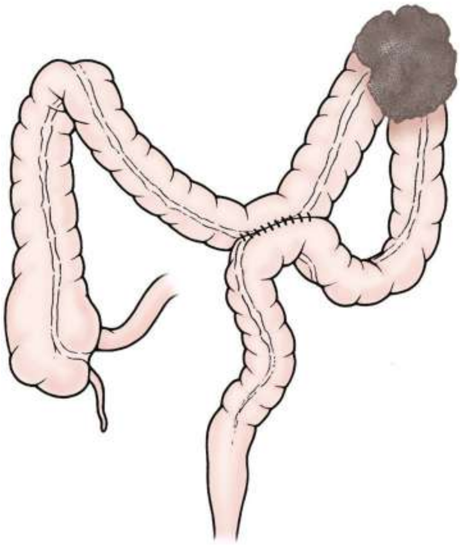
Attention is now turned to the proximal end and its viability is checked. If there is any doubt, it must be resected back to well-vascularised bowel. It should reach without tension to the anastomotic site and, if difficulty is encountered, a second higher division of the inferior mesenteric vein below the body of the pancreas, as routinely performed in an anterior resection, provides extra length. The anastomosis may be performed using either a hand-sewn technique or a circular stapling device (see Chapter 25). The surgeon will find a difficult hand-sewn anastomosis easier if the first suture is placed on the posterior wall furthest away, taking the initial bite from the rectal side of the anastomosis. If this suture is accurately placed, then each subsequent suture, when working along the back wall, becomes easier. The anterior wall poses no difficulty unless mobilisation has been inadequate and there is unacceptable tension. No drain is recommended unless there has been more extensive pelvic dissection.

Variations A radical lymphadenectomy, with ligation of the inferior mesenteric artery close to its origin, will often still allow preservation of the entire descending and sigmoid colon on the marginal artery. Therefore, it is sometimes possible, in patients with a distal sigmoid tumour, to perform a radical resection and still have sufficient length to anastomose without the need to mobilise the splenic flexure (see Figure 14.8b).

A locally advanced left colonic neoplasm may be unresectable. Obstruction can be relieved by an intraluminal stent or a proximal loop colostomy. A splenic flexure tumour can sometimes be bypassed (Figure 14.11).

Laparoscopic left hemicolectomy

The patient is placed in the Lloyd-Davies position with shoulder supports to prevent patient slippage on the table. Port sites will depend on the preference of individual surgeons, but one satisfactory arrangement



14.11 An irresectable splenic flexure tumour with invasion of the spleen, pancreas and kidney can be bypassed with a side-to-side anastomosis between the transverse and sigmoid colon. ⏎

is an umbilical camera port, a 12 mm main working port placed just above the right anterior superior iliac spine and an additional 5 mm port in each flank.

A medial to lateral approach is commonly used to mobilise the left colon, as with a lateral approach, such as that used in open surgery, the fully mobilised sigmoid colon can obscure the operative field. The patient is positioned steeply head down, and the omentum, transverse colon and small bowel are moved as much as possible into the right upper quadrant to expose the mesentery of the sigmoid colon. This mesentery is grasped near the distal sigmoid colon and retracted laterally and towards the anterior abdominal wall by an assistant. This places the inferior mesenteric artery under tension and makes its course visible through tenting the overlying mesentery. The retroperitoneal plane is then entered by an incision in the peritoneum, which starts to the right of the inferior mesenteric artery at the pelvic brim and continues to the origin of the inferior mesenteric artery. Blunt dissection opens up this plane behind the mesentery, which is then developed laterally in a similar fashion to the dissection in a laparoscopic right hemicolectomy.

The ureter is encountered early in this plane and should be pushed posteriorly to prevent it being lifted with the mesentery. This dissection should be developed laterally behind the colon as far as the colonic peritoneal attachment to the abdominal sidewall and continued up towards the splenic flexure. Once the dissection has passed behind the inferior mesenteric artery, a window is made through the mesentery on the lateral side, and the vessel is divided with a vascular laparoscopic stapler or clipped and divided.

The remainder of the mobilisation of the left colon now proceeds with the division of any adhesions from the sigmoid colon to the abdominal sidewall, followed by lateral division of the peritoneum continuing upwards towards the splenic flexure. As the splenic flexure is approached, the head-down tilt can be reduced to bring the bowel closer to the surgeon. If mobilisation of the splenic flexure is required, this is done with the patient in a reverse Trendelenburg position. The plane between the transverse colon and the omentum is entered and dissection proceeds distally as in an open operation.

Once the colon is sufficiently mobilised, the distal resection is carried out. This is usually at the level of the upper rectum to allow a stapled anastomosis to be created with a circular stapling device. The mesorectum is divided with the Harmonic™ scalpel or an alternative energy source and the bowel with a linear stapler. Mobilised colon and tumour are then delivered through an incision, which may be periumbilical, in the left iliac fossa, or a Pfannenstiel incision as per the surgeon's preference. The wound edges must be protected.

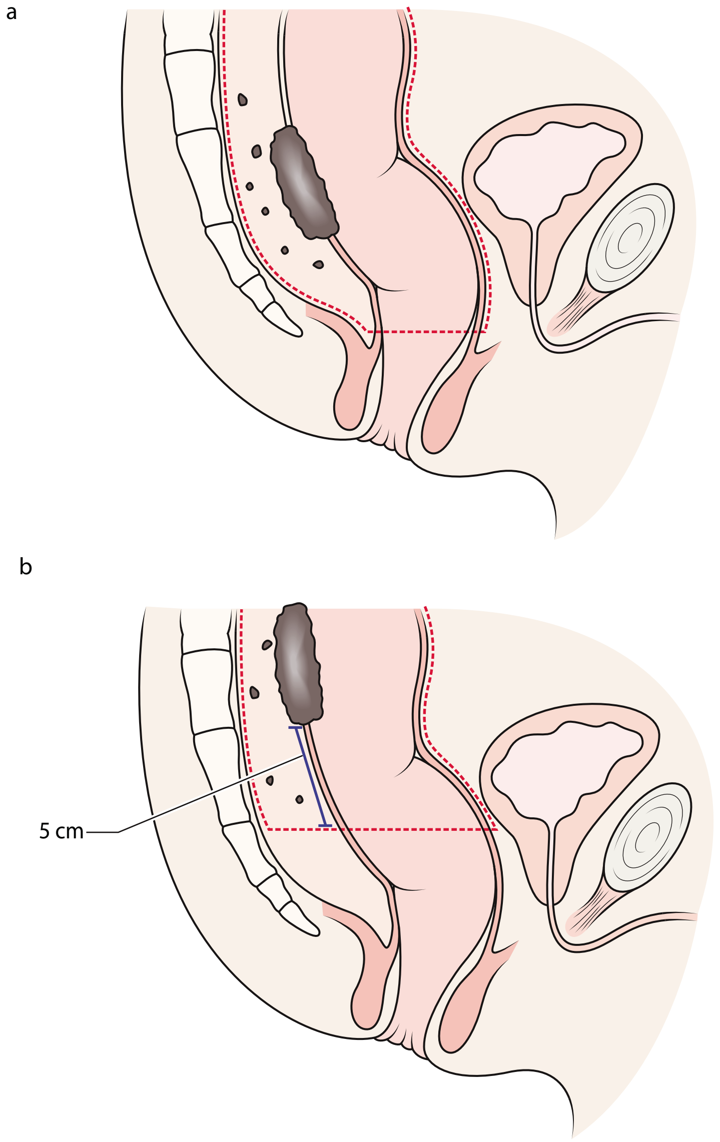
The proximal bowel is divided, with care taken to ensure that there is adequate length for the bowel to reach an anastomosis without tension. The anvil of the circular stapler is then secured within the divided bowel with a purse-string suture and returned to the peritoneal cavity. The incision is closed, the pneumoperitoneum is re-established and the circular stapling device is introduced through the anal canal. The delivery of the spike through the stapled rectal stump, the locking of the anvil onto the spike and the closure of the stapler to approximate the bowel are completed under direct laparoscopic vision.

RADICAL RECTAL RESECTIONS

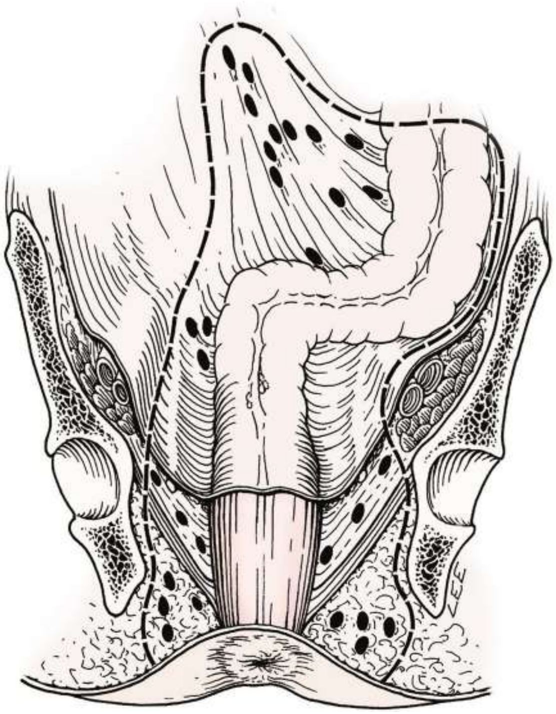
HISTORICAL PERSPECTIVE

A radical resection for a carcinoma of the rectum requires excision of the primary tumour in continuity with its lymphatic drainage. The earliest attempts at excision were performed from the perineum or through a *posterior* approach.[5] These approaches do not offer sufficient access for a radical lymphadenectomy.

Abdominoperineal excision of the rectum later became the standard radical excision for rectal cancer, with the opportunity to include a radical lymphadenectomy. However, an increasing understanding of the mode of spread and lymphatic drainage of rectal cancers has resulted in the conclusion that a purely abdominal procedure, or *anterior resection* of the rectum, is oncologically safe and effective for the vast majority of cases, with the exception of the very lowest or most advanced rectal cancers. There is no significant submucosal spread of either rectal or colonic tumours, and it is therefore safe to resect a rectal cancer with a distal bowel wall margin of around 1 cm. The lymphatic drainage of the rectum is almost exclusively in a proximal direction along the inferior mesenteric artery. Lymphatic drainage in association with the inferior or middle rectal arteries in low rectal cancer continues to be an area where the Japanese experience differs from that in the West.[6] In the UK, it is generally believed that lateral spread only occurs late in the disease process and is associated with advanced and incurable tumours. However, the initial lymphatic drainage of the tumour fans out into the mesorectum, and at least 5 cm of mesorectum distal to the lower luminal edge of the tumour should be excised (Figure 14.12). Therefore, any tumour within 10–12 cm of the anal verge requires a total mesorectal excision (TME). If the mesorectum involved in the tumour is breached during dissection, local recurrence is common. Originally, local recurrence was thought to be related both to residual tumour in the distal bowel wall remnant as a result of submucosal spread and to lymphatic drainage along both surfaces of the levator ani muscles and out into the ischiorectal fossae (Figure 14.13). It is now known that neither route of spread is a significant issue. These, however, were the oncological justifications for the abdominoperineal resection. In addition, before the



14.12 The initial spread from a rectal tumour into the mesorectum is fan shaped. Nodes up to a distance of 5 cm distal to the primary tumour may contain metastases. (a) A total mesorectal excision (TME) is required for all tumours within 10 cm or so of the anal verge as lymphatic spread can occur for up to 5 cm below the distal luminal edge of the tumour. (b) For higher rectal cancers the mesorectum can be transected 5 cm below the lower edge of the luminal tumour. ⏎



14.13 The original hypothesis of the lymphatic drainage of the rectum, as described by Ernest Miles, which formed the oncological basis for the abdominoperineal excision of the rectum for cancer. It is now known that no lymphatic drainage occurs through the levator muscles into the ischiorectal fat from tumours above the dentate line. ⏎

advent of mechanical staplers, the technical difficulty in hand-sewn anastomoses deep in the pelvis usually discouraged anal preservation. An abdominoperineal approach can, at least in theory, be avoided in all rectal cancers except those that extend to the dentate line or invade the anal sphincters.[7] Excision of very low rectal cancers is technically difficult and, as better results are achieved by surgeons with a special interest, referral should be considered. The preoperative assessment of these tumours is extremely important for the planning of surgery and of any adjuvant therapy, and this is discussed further later in this chapter. In addition to pelvic MRI scanning, a preoperative digital assessment and endoanal ultrasound examination, either in the awake patient or under anaesthesia, can form an important part of the assessment of very low tumours.

ANTERIOR RESECTION

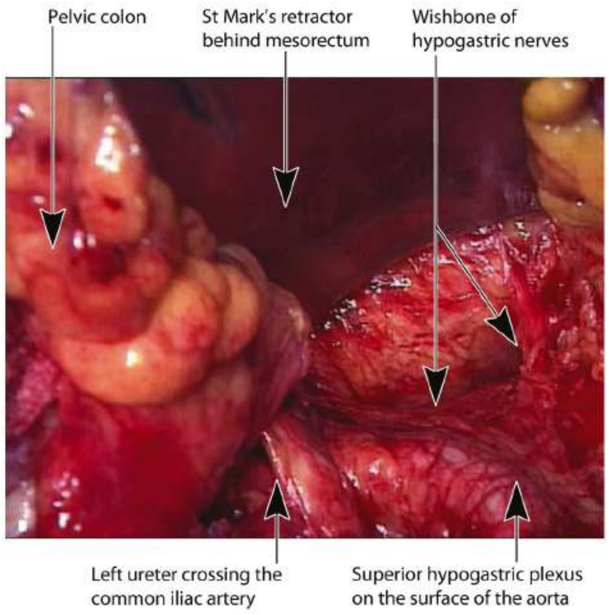
The principles of an anterior resection are similar for open and laparoscopic surgery and so will be described together. Laparoscopic surgery often gives a better view in a narrow pelvis, but obtaining good retraction can be more difficult at laparoscopy. If there is concern during surgery as to whether a good oncological resection can be completed laparoscopically, then conversion to an open operation is mandatory.

The patient is placed in the Lloyd-Davies position and the operation commences with a digital rectal examination (and vaginal examination in women) to assess the tumour. The abdomen and perineum are prepared for surgical access. Postoperatively, there are advantages with suprapubic rather than urethral catheterisation, in particular for men, who may have a degree of prostatic outflow obstruction. The technique and its advantages are discussed in Chapter 25. The initial mobilisation and dissection for an anterior resection are identical to that for a left hemicolectomy, unless there is a minor modification to avoid mobilisation of the splenic flexure. This modification is dependent on the sigmoid colon proving suitable for reconstruction. If there is any diverticular thickening, a sigmoid neorectum is rendered unsuitable due to reduced distensibility. In addition, the sigmoid colon may have a precarious blood supply after division of the inferior mesenteric artery. Vascularity of the sigmoid colon may be improved by retention of the ascending left colic artery, which arises as a branch of the inferior mesenteric artery within 2–3 cm of its origin (see Figure 13.2). Radicality of the lymphadenectomy is probably not significantly reduced if, on skeletonisation of the artery prior to dividing, all of the fat and lymphatic tissue is drawn into the specimen.

In most situations, however, the surgeon will have decided to mobilise the splenic flexure, and this is often most satisfactorily performed before the pelvic dissection. A single division of the inferior mesenteric vein, at the level of the division of the artery, still leaves the vein as a cord at the base of the mesentery, preventing the descending colon from reaching to the pelvic floor. A second higher ligation of the inferior mesenteric vein at the lower border of the pancreas affords excellent extra mobility of the left colon. The transverse mesocolon is retracted upwards and the inferior mesenteric vein is then usually readily identified. The flimsy peritoneum is dissected on the left side of the duodenojejunal flexure to enter a bloodless plane either side of the inferior mesenteric vein. The vein is then either divided between artery forceps and ligated, or clipped. Care must be taken over this step, as an unsecured vein may retract underneath the pancreas and cause troublesome bleeding. For example, it is important to ensure that a proximal ligature is tied securely, with an adequate venous remnant beyond the ligature. After this high division of the vein, the surgeon will encounter a large mesenteric window of peritoneum, extending between the ligated distal vein and the marginal artery. This can be divided, carefully preserving the marginal vessels, to allow the left colon to be drawn down into the pelvis. This manoeuvre leaves an isolated segment of the inferior mesenteric vein in the mesentery.

Posterior pelvic dissection

After full mobilisation of the left colon, dissection of the posterolateral plane is then continued down into the pelvis. The rectum and mesorectum are lifted forwards and upwards, out of the concavity of the sacrum. In the open operation, this retraction is with a St Mark's retractor, while retraction can be achieved laparoscopically when combined with Johan grasping forceps. One set of forceps is placed on the distal sigmoid mesocolon and is held by the assistant; the second is held in the left hand of the surgeon. It is this retraction that displays the plane for dissection. The mesorectum should appear as a smooth bilobar structure with a glistening surface suggestive of a 'capsule' and similar to that of a lipoma. The plane is between this and the thin fascia covering the structures of the pelvic sidewall and is crossed by fine strands of areolar tissue. The autonomic nerve plexi are located deep to the pelvic sidewall fascia. If the areolar plane is opened by blunt dissection, it does not separate accurately and both the autonomic nerves and the mesorectum may tear. The incidence of postoperative urinary and sexual dysfunction will be increased and there is a greater risk of local tumour recurrence. Sharp dissection is by scissors, diathermy or a Harmonic scalpel. Diathermy or Harmonic dissection is more haemostatic than scissors, but more dangerous if the surgeon strays from the correct plane. Thermal damage to anatomically intact autonomic nerves is an additional concern. The 'wishbone' of the sympathetic hypogastric nerves will be visible at the pelvic brim posteriorly, and these nerves are easily injured if the dissection strays too far posteriorly (Figure 14.14). If the correct plane on the front of the aorta, between the back of the pelvic mesocolon and the superior hypogastric plexus, has been identified, this will lead the dissection into the pelvis in the correct plane medial to the hypogastric nerves. There is a second areolar plane outside the nerves, but this should be followed only for a tumour that is threatening circumferential excision margins at this site. This outer plane sacrifices autonomic nerves, and troublesome bleeding may occur from presacral veins. The final posterior dissection is in a forwards direction, beneath the lobes of the mesorectum, along the surface of the levator muscles, but is completed only when mobility has been increased by the lateral and anterior dissection.

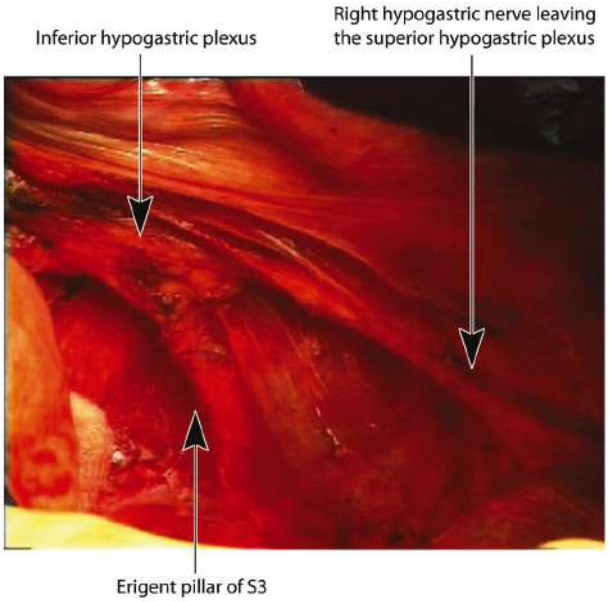

Pelvic colon
St Mark's retractor behind mesorectum
Wishbone of hypogastric nerves
Left ureter crossing the common iliac artery
Superior hypogastric plexus on the surface of the aorta

14.14 View looking down into the pelvis during mobilisation of the mesorectum. ⏎

The lateral plane on the surface of the mesorectum is best approached from the plane already developed posteriorly. It may be difficult to identify from above and, therefore, early lateral division of the peritoneum may merely lead the surgeon into the wrong plane. The hypogastric nerves are easily damaged at this stage, but the correct plane of dissection on the lateral surface of the mesorectum will allow the hypogastric nerves, and then the inferior hypogastric plexi, to fall back safely onto the pelvic sidewall. The small rectal branches from the plexi cross the plane of dissection and are divided. The original descriptions of lateral ligaments, which were clamped and ligated, were probably the hypogastric plexi tented away from the pelvic sidewall by medial traction on the specimen. The middle rectal artery, if present, will also cross the areolar plane and requires diathermy coagulation or, occasionally, ligation. Earlier descriptions of large middle rectal vessels were almost certainly vessels in the mesorectum encountered when dissection was too medial and through, rather than around, the mesorectum. The 'pillar' of the erigent nerve, which is the parasympathetic outflow from S3 to the inferior hypogastric plexus, can be identified beneath the fascia of the pelvic sidewall (Figure 14.15). It is at risk of injury if the deep dissection strays too lateral. It is now known that the circumferential margin, clear of cancer, is important in preventing local recurrence in rectal cancer.[8] However, dissection in the correct plane will normally ensure adequate margins, except in advanced tumours that have transgressed the confines of the mesorectum. In these circumstances, the surgeon may be forced to sacrifice pelvic autonomic nerves to achieve adequate oncological clearance.

Anterior pelvic dissection

Male patients The anterior plane in the male pelvis lies between the thin anterior mesorectal tissue


Inferior hypogastric plexus
Right hypogastric nerve leaving the superior hypogastric plexus
Erigent pillar of S3

14.15 The right lateral pelvic sidewall after full rectal mobilisation. ⏎

and the prostate and seminal vesicles. It is entered by incising the peritoneum just anterior to the rectovesical pouch and entering an areolar plane, which leads to the upper pole of the seminal vesicle. Alternatively, the lateral dissection, when carried forwards on the surface of the mesorectum, will lead around to the vesicles. An anterior tumour that has invaded the peritoneum and folded over with a malignant adhesion is easily disrupted at this point. The anterior pelvic peritoneal incision shown in Figure 14.10b should be made more anteriorly in this situation. Forceps or a laparoscopic grasper can then be applied to the divided peritoneum to hold it up and hold this vulnerable area closed and prevent rupture. This should help prevent traction disruption of the tumour during the deeper pelvic dissection. The dissection is kept on the posterior surface of the seminal vesicles. Denonvilliers' fascia comes into view as a shiny white layer on the anterior surface of the distal anterior mesorectum. Dissection is continued down in front of Denonvilliers' fascia. This thin fascial rectogenital septum forms a temporary barrier to anterior tumour invasion. Distally, Denonvilliers' fascia curls forwards to fuse with the base of the prostate and must, therefore, be divided at some stage during the rectal excision and the plane directly on the anterior mesorectum re-entered. The final anterior dissection in front of Denonvilliers' fascia puts the neurovascular bundles and the prostatic plexus at risk of injury. It is therefore safer to cut Denonvilliers' fascia at a higher level and to continue any final dissection behind it. In very low anterior tumours, however, the risk of nerve damage must be balanced against involved tumour margins, and the dissection should proceed more distally before dividing Denonvilliers' fascia.

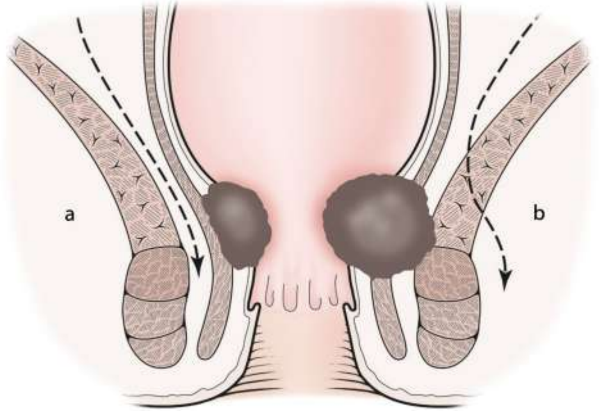
Female patients The anterior plane in the female pelvis lies between the thin anterior mesorectum and the posterior vaginal wall. Avoidance of nerve damage is also important but, until recently, has been largely ignored. Denonvilliers' fascia is a less well-developed structure, and an anterior tumour can breach the thin layer of anterior mesorectum relatively early. A cuff of posterior vagina should be included with the specimen if there is vaginal invasion or any concern over circumferential tumour margins at this point.

These tumours may require a more radical excision, including the sacrifice of autonomic nerves with the removal of internal iliac nodes, an *en bloc* hysterectomy and excision of a seminal vesicle or a portion of involved prostate or bladder. A full anterior pelvic clearance (pelvic exenteration) with urinary diversion is occasionally justified (discussed later in this chapter). These locally advanced tumours require careful preoperative assessment and multidisciplinary management with a combination of surgery, radiotherapy and chemotherapy for optimal results.

Final pelvic dissection

The final dissection is important in very low tumours. A posterior condensation of fascia between the coccyx and the anorectum is released to display a bare rectal muscle tube below the mesorectum, which passes through the puborectalis portion of the levator ani. Anteriorly, the dissection passes through Denonvilliers' fascia onto the distal extremity of the thin anterior mesorectum and finally, below this, onto the bare rectal muscle tube. The anatomical plane between the visceral and somatic structures continues into the intersphincteric plane. A tumour at the anorectal junction, which is still a T2 lesion, can thus sometimes be adequately excised by following this plane. However, a T3 tumour in this position has no mesorectum around it and will immediately breach the plane and invade the external sphincters (Figure 14.16). An abdominoperineal excision then becomes essential for oncological clearance.

After completion of the dissection, the rectum should be sealed below the tumour to prevent further contamination from intraluminal malignant cells. At open surgery, the simplest technique is with a TA™ 30 or 45 stapler (30 or 45 mm length) or with a similar linear stapler (see Chapter 7). This is a safer method of occlusion than with a right-angled clamp, which may slip and is difficult to position in a narrow pelvis. This staple line seals the distal end of the specimen to be removed. It must be below the tumour, but a margin of only a few millimetres does not compromise cure. The tumour is normally palpable through the



14.16 A lower-third rectal cancer. (a) A T1 or T2 tumour, which has not breached the plane between the visceral and somatic tissue, can still be satisfactorily excised without sacrifice of the external sphincter. (b) A T3 tumour will breach this plane, as there is no mesorectum surrounding the bowel at this level. An oncologically satisfactory excision is no longer possible without sacrifice of the external sphincters. The plane for an anterior resection must be abandoned before the tumour is breached, and the plane for excision is through the levator ani muscles. ⏎

rectal wall, but if there is any concern, an examination from below, after the stapler is locked (but still not fired), can confirm the position. In a mid-rectal tumour, although a TME has been performed, the mesorectum is drawn up as the stapler is closed and a short cuff of distal rectum is left *in situ*. In a cancer of the distal rectum, the stapler may have to be closed beyond the distal margin of the mesorectum in order to clear the tumour. The height of the anastomosis may therefore vary by 1–2 cm, even after a TME.

A proctoscope is inserted and the rectum washed with water until the effluent is clear of faecal residue. The TA 30 is then reloaded and placed distal to the first staple line and fired across the washed rectal stump. In very low tumours, this manoeuvre is easier if the TA 30 is left *in situ* after firing, to be used as a rectal retractor, and a new stapler used for the second staple line. The bowel is divided between the two lines of staples.

The staplers used in laparoscopic surgery divide as well as staple, so cannot be used to occlude the bowel prior to the washout. This can be done instead through the application of long-bladed Johan grasping forceps across the bowel as a clamp immediately distal to the tumour. Division of the bowel is performed with a stapler with an angled head, introduced through the 12 mm port near the right anterior superior iliac spine. The tumour and mobilised bowel can then be retrieved through a short transverse suprapubic incision with protected wound edges.

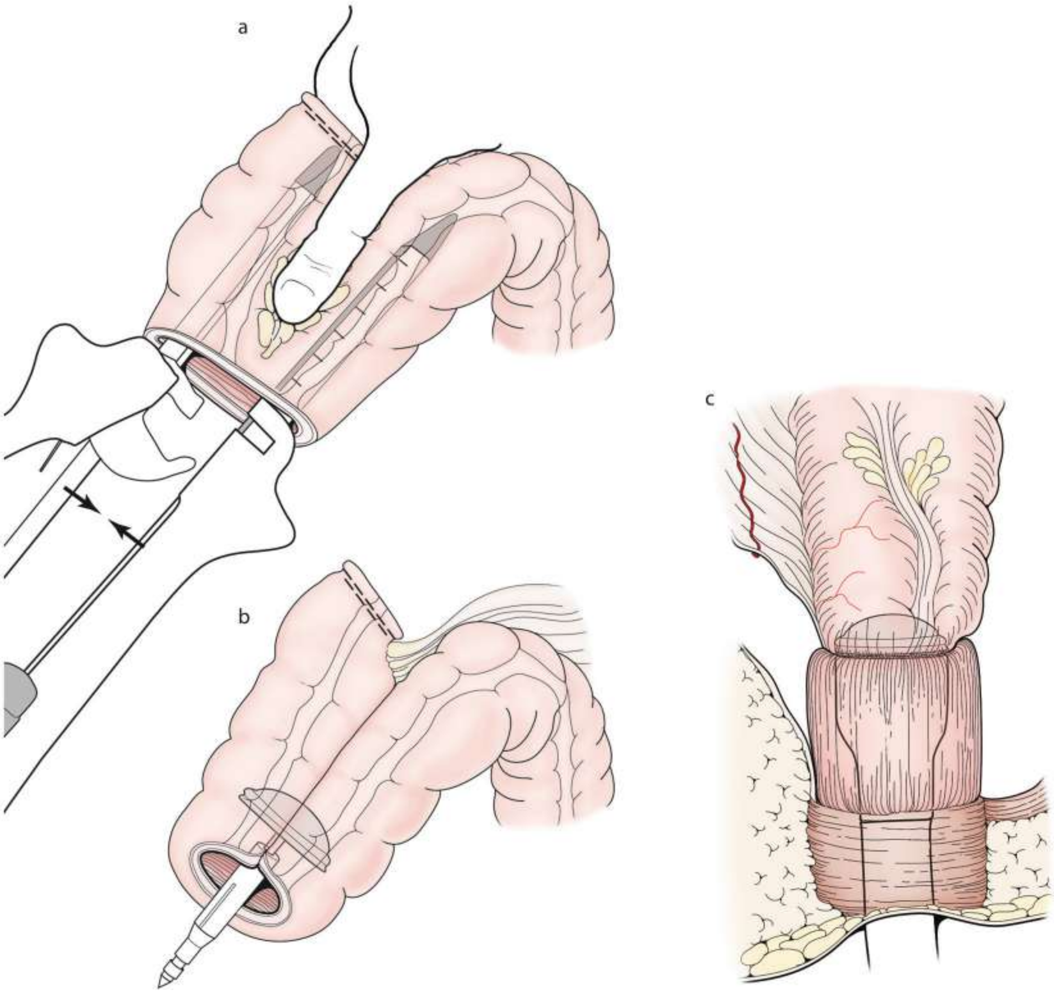
Reconstruction

The proximal bowel end is now reassessed for reconstruction. It must reach with ease into the depths of the pelvis, and further mobilisation may be required, especially if the original division of colon has had to be revised to a higher level to ensure a well-perfused bowel end. Further length can be obtained by dissection along the inferior border of the pancreas, releasing the left lateral attachment of the transverse mesocolon as far as the origin of the middle colic artery. There is frequently a small branch between the colonic mesentery and the inferior pole of the pancreas. This can be ligated and divided. Care must be taken with this manoeuvre, as simple diathermy will often lead to troublesome bleeding from the pancreas. Where there is still inadequate length, the left branch of the middle colic artery is often smaller than the more centrally placed branch and it can be divided near its origin. Once again, a window can be created extending to the marginal artery, and this can produce excellent length. If, on completion of this mobilisation, it is still clear that there is insufficient length, three options are available to the surgeon:

1. The first is to transilluminate the mesentery and assess whether there are suitable points where vessels can be ligated.
2. The second, which can often produce considerable improvement in mobility, is to mobilise the whole of the right colon. This is undertaken from the lower pole of the caecum around the hepatic flexure, such that the middle colic artery can be rotated downwards. The appendix and caecum will then frequently lie in the right upper quadrant, and considerable additional length can be achieved.
3. If, following these two manoeuvres, there is still inadequate length or the bowel does not appear to have sufficient vascularity for a safe anastomosis, then the preferred option is to divide the origin of the middle colic artery. The mobilised caecum is moved downwards like a clock pendulum, such that the lower pole of the caecum sweeps in an arc towards the left iliac fossa and then up into the left upper quadrant. This leaves a long, well-vascularised segment of bowel in the region of the hepatic flexure available for a tension-free coloanal anastomosis.

After a TME and a low anterior resection, bowel function and continence were found to be better if a short colon pouch was created rather than forming a straight end-to-end coloanal anastomosis.[9] A short colon pouch (5 × 5 cm) is created with a GIA™ 60 linear stapling device. An enterotomy is made on the antimesenteric border about 6 cm from the closed end. The blades of the stapler are introduced and a finger is swept between the blades to carry the mesentery out of the staple line before the device is closed. The instrument is then fired to anastomose the two limbs into a pouch (Figure 14.17a). The head of the circular stapling device is introduced into the pouch through the enterotomy made for the introduction of the linear stapler (Figure 14.17b). A purse-string suture is inserted at the edge of the enterotomy and tightened to draw the bowel over the staples. In a laparoscopic anterior resection, these steps can most easily be performed outside the abdomen after delivery of the specimen. The general principles of circular stapling techniques are described in Chapter 7. The main portion of the circular stapler is inserted through the anus. Care must be taken to cause minimal stretching of the anal sphincters, and gentleness and good lubrication are essential. The spike of the locking device is advanced through the anorectal stump, adjacent to the stapled closure. The bowel ends must then be orientated to exclude a twist before locking the two portions of the circular stapling device together. It is very easy to inadvertently include the vagina in the staple line, and it must be securely retracted out of the way as the two bowel ends are apposed (Figure 14.17c). The device is fired and removed. The 'doughnuts' of excised tissue from both bowel ends are removed from the stapler and checked to ensure that they are complete. The anastomosis is further checked for leaks by filling the pelvis with fluid, occluding the bowel above the pouch and introducing about 200 mL of air through the anus. Bubbles appearing in the fluid-filled pelvis indicate a leak.

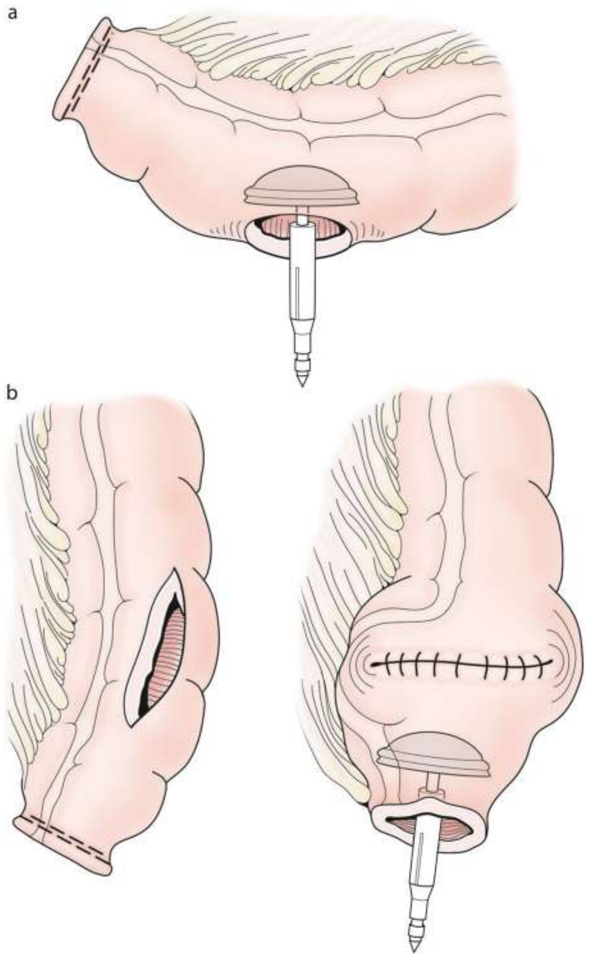
The pouch fills the cavity of the sacrum and reduces the pelvic dead space in which a haematoma can collect. This may reduce the incidence of anastomotic leak, as the spontaneous discharge of infected collections of blood into the bowel lumen, through



14.17 A colon pouch is created with a linear stapling device introduced through an enterotomy about 6 cm from the closed bowel end. (a) The thick colonic mesentery must be swept out of the staple line with a finger before the device is closed and fired. (b) The head of the circular stapling device is then introduced into the colon pouch through the same enterotomy. (c) The anvil of the circular stapling gun is introduced through the anus, the two portions of the device are locked together and the bowel ends are approximated. ⏎

the anastomosis, is believed to be a factor in the aetiology of a leak. Low-pressure suction drains may also be of value. These should be liberally primed with washout fluid, which is left in the pelvis at the end of the operation in order to prevent occlusion of the drain with clots. Any anastomosis where there is technical concern, and probably all coloanal anastomoses, are safer if they are protected by a temporary defunctioning loop ileostomy or colostomy.[1] Preoperative chemotherapy and radiotherapy will also make this anastomosis more vulnerable to leakage and should influence the decision reached regarding a temporary stoma. A stoma should not be closed until a water-soluble enema has shown the anastomosis to be intact, without leakage, and a delay of 6–8 weeks is ideal.

Variations Some surgeons prefer to use a per-anal, hand-sutured coloanal anastomosis in extremely low cases, and this technique is described in the section on ileoanal pouches in Chapter 13. An alternative to a small colon pouch is a stapled end-to-side anastomosis (Figure 14.18a). This also reduces faecal urgency when compared with a straight coloanal anastomosis, and the increased bulk in the pelvis during the immediate postoperative phase may also reduce postoperative pelvic collections and anastomotic leaks. Another alternative is a straight coloanal anastomosis with an anterior vertical enterotomy that is closed transversely (Figure 14.18b). Both colon pouches and end-to-side anastomoses have the additional advantage that the better-perfused side, rather than the end, of the colon is used for the anastomosis.



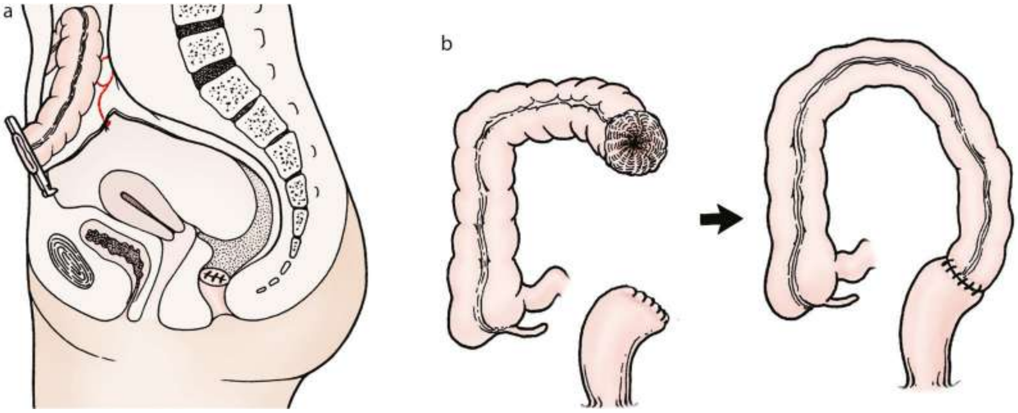
14.18 (a) An end-to-side anastomosis. (b) An end-to-end anastomosis, but with a small colon pouch created by an anterior coloplasty. ⏎

High anterior resection

This operation consists of transection of the mesorectum and preservation of the distal rectum. It may be performed in diverticular disease when a sigmoid loop is folded down and is adherent to the front of the rectum and cannot be safely released. A distal sigmoid tumour and the most proximal rectal tumours are also appropriate indications for this operation. It is essential, however, that 5 cm of mesorectum is excised beyond any tumour, and the surgeon must avoid 'coning in' through the mesorectum, as this results in compromised lymphatic clearance (see Figure 14.12). It is therefore still necessary to mobilise the rectum, and the dissection is similar to that for a low anterior resection, except for the deepest parts of the dissection. The site of rectal division is chosen and, by dissecting close to the lateral and then the posterior rectal wall of the bowel, a window is created between the rectum and its mesentery. In open surgery, the mesentery with the terminal branches of the superior rectal artery are then divided between artery forceps and ligated, while laparoscopically an energy device, such as the Harmonic scalpel, is used. Access is difficult for a hand-sewn anastomosis, and a circular stapling device is usually preferred. A straight end-to-end or side-to-end colorectal anastomosis is satisfactory, but a colon pouch should not be used at this level, as this can lead to constipation. A defunctioning stoma is not usually indicated unless there is some specific concern about the anastomosis.

Hartmann's procedure

In this operation, following a large bowel resection, the distal bowel is closed and left *in situ* and the proximal end is brought out as an end colostomy. After an anterior resection for rectal cancer, the surgeon may decide that a permanent stoma is wiser in a patient with very poor anal sphincters. In this situation, only an anorectal stump, closed by staples, is left *in situ* (Figure 14.19a). No later reconstruction is anticipated, but preservation of the anus avoids the additional morbidity associated with the perineal wound



14.19 Hartmann's procedure. (a) An end stoma is an alternative to restoration of bowel continuity after the anterior resection of a rectal cancer. Later restoration of continuity is then seldom undertaken. (b) After a sigmoid resection for diverticular disease, a longer distal stump remains. If immediate anastomosis is contraindicated, later restorative surgery is usually considered. ⏎

of an abdominoperineal excision of the rectum. An alternative in this situation, preferred by many surgeons, is to do an intersphincteric resection of the anorectal stump, with the external sphincter sutured to close the defect.

Although originally described as an operation for rectal cancer, Hartmann's procedure is now employed more frequently in conjunction with an emergency sigmoid resection, for the complications of diverticular disease (see Chapter 7). A Hartmann's procedure has the advantage of shortening the operation time and avoiding the risk of an anastomotic leak. However, restoration of continuity requires a second operation, which may be difficult and complex. Therefore, the alternative of a primary anastomosis with a temporary defunctioning proximal loop stoma should always be considered, as the loop stoma can be closed as a much more minor second procedure compared with reversal of a Hartmann's procedure.

When later restoration of bowel continuity after a Hartmann's procedure is anticipated, the distal bowel end should be marked with a non-absorbable suture, with the ends cut long, to make subsequent identification easier. A long stump may make reversal easier, especially if a hand-sewn anastomosis at open operation is anticipated.

Reversal of a Hartmann's procedure

Reversal is often not in the best interests of the patient. The original decision not to restore continuity and the length of the rectal stump that has been left *in situ* are important factors in the decision-making process. Reversal should be delayed for 3–6 months to allow reduction in inflammation associated with the underlying pathology and the original operation. A long stump, which has been brought up to lie just beneath the lower end of the abdominal wound, will be relatively easy to identify at laparotomy, and a hand-sewn anastomosis will be practical. More often, the stump includes very little rectum above the peritoneal reflection, and although the operation may be straightforward, a number of difficulties may be encountered. The rectal stump must be identified, the end stoma dissected out and the two ends anastomosed (Figure 14.19b). The stump may be difficult to identify, and access for a hand-sewn anastomosis can be limited without mobilisation of the rectum. Use of the circular stapling device does not always solve this difficulty. It may not pass up the rectal stump until rectal folds have been straightened out by mobilisation, and the defunctioned rectum may also have narrowed down and be unable to accommodate the stapler without splitting of the muscle tube. Restoration of continuity to a very short stump, as shown in Figure 14.19a, can be achieved relatively easily with a circular stapling device, but the empty pelvis may have adherent loops of small bowel and the initial dissection to free these adhesions can be tedious. In addition, the proximal bowel end may not reach down safely for the anastomosis until it has been further mobilised.

Reversal of a Hartmann's procedure can also be performed laparoscopically. All the abdominal dissection is undertaken laparoscopically and the anastomosis is performed with the circular stapling device. Usually the end stoma is mobilised, the peritoneal cavity entered and pneumoperitoneum established using a seal at the stoma site. Conversion to an open operation may be required if extensive adhesions are encountered such that the surgeon is unable to safely mobilise the tissues laparoscopically.

ABDOMINOPERINEAL EXCISION

Abdominoperineal excision was the classic operation for both anal and rectal cancer, but the indications for this operation are dwindling. Squamous cell anal carcinoma is now managed by chemoradiotherapy, and abdominoperineal resection is reserved for the occasional salvage situation. In rectal cancer, an abdominoperineal excision involved removal of all the tissue around the rectum that was believed to be at risk of lymphatic involvement (see Figure 14.13) and, in addition, removal of the anal stump, which was thought to be at risk of intramural tumour spread. In the light of present knowledge, there is therefore no oncological benefit in sacrificing the anus in the majority of patients with rectal cancers, and in specialised centres the percentage of rectal cancers requiring abdominoperineal excision continues to fall. There are, however, some low rectal adenocarcinomas that are invading the anal sphincters or extending dangerously close to the plane of dissection at this level, and sacrifice of the anal sphincters becomes inevitable for good oncological clearance (see Figure 14.16).

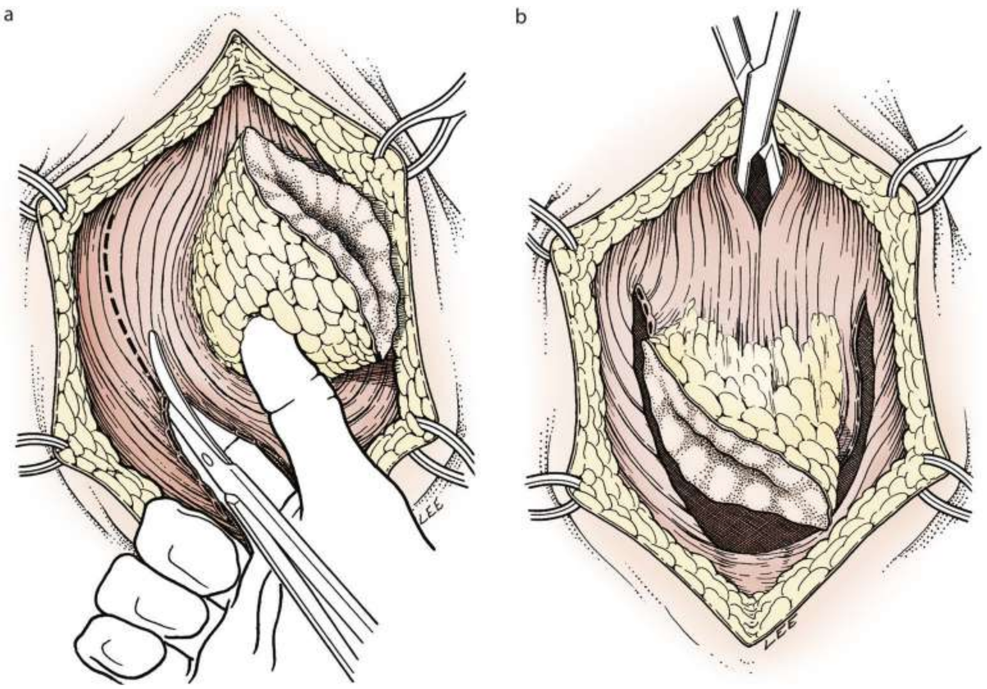
A separate issue is that of restoration of continuity after a low anterior resection. Before the advent of circular stapling devices, the difficulty of a hand-sewn anastomosis deep in the pelvis was a major deciding factor. Although it is now almost always technically possible to restore continuity after an anterior resection for an upper or mid-rectal tumour, it may still be inadvisable in a patient with very poor sphincter function. There is, however, no advantage in excising the anal canal and sphincters and inflicting an additional perineal wound. This situation is an indication for a low Hartmann's procedure or, alternatively, an intersphincteric resection of the anorectal remnant. However, as the deep aspects of an anterior resection for a lower-third rectal cancer can be technically very difficult and unnecessarily close to tumour, the surgeon may opt for an abdominoperineal resection if a restorative operation is felt to be contraindicated.

Operative procedure

The abdominal dissection is very similar to that for a low anterior dissection. It can be undertaken as an open or laparoscopic operation. The plane immediately outside the mesorectum is developed to mobilise the upper and mid rectum. This plane, however, should not be followed distally, as it cones in below the mesorectum on the surface of the levators, or the circumferential margins will have been narrowed at the level of a low tumour (see Figure 14.16). Posteriorly, the dissection should stop when the pelvic floor musculature, with the overlying parietal pelvic (Waldeyer's) fascia, is first encountered. This is particularly important in cases where the tumour is either too low or too locally advanced for an anterior resection ever to have been an option. These tumours are below the mesorectum and their main protective covering is the 'cradle' of the levators.

The operation then continues from the perineum. An extralevator abdominoperineal excision (ELAPE), whereby the plane of excision is outside the levators, leaving the levators on the specimen, is now considered to be the optimal technique.[2] Turning the patient prone at this stage gives a better view.[10] If this is to be done, then the abdomen is closed and the end colostomy performed prior to turning the patient. The dissection commences with a purse-string suture, inserted just outside the anal verge, to seal the anus and prevent any contamination of the perineal wound with mucus or blood from the tumour. The anus is then circumscribed with an elliptical incision, and laterally the dissection enters the ischiorectal fat. The dissection is deepened posteriorly towards the coccyx, which is a palpable landmark for the surgeon. The initial entry through the pelvic floor is a transverse incision immediately in front of the tip of the coccyx, although the alternative of excising the coccyx with the specimen has the advantage of leading the surgeon more naturally into a radical clearance of the lateral pelvic floor. The midline incision must go through Waldeyer's fascia to enable the surgeon to insert a finger into the supralevator compartment of the pelvis. This step can be recognised by the arrival of blood from the abdomen into the perineal wound. Failure to break through this fascia results in stripping of the parietal fascia, with subsequent tearing of pelvic veins and autonomic nerve damage. Rotation of the hand allows the levator muscle to be steadied, between finger above and thumb below, while it is divided near its attachment to the pelvic sidewall and well lateral to the tumour and the sphincter complex (Figure 14.20a). The dissection is carried around on both sides.

Anteriorly in the male patient, the lower edges of the transverse perinei muscles are sought. The dissection should be immediately behind these muscles in order to enter the embryological plane between the rectal and urogenital structures. This plane can be difficult to define, and the surgeon is concerned, particularly in the case of anterior tumours, with obtaining adequate oncological clearance yet at the same time wishing to avoid damage to the urethral bulb. A urethral catheter is a useful guide at this point, as it can be palpated. If the perineal dissection is carried out supine, then the abdominal surgeon can guide the perineal surgeon into the correct plane, in the midline anteriorly, as the initial breakthrough into the supralevator compartment is made (Figure 14.20b). It is important that the anterior plane has been dissected adequately from above. Only the anterior pillars of puborectalis still remain intact. A finger



14.20 The perineal dissection of an abdominoperineal excision of the rectum. (a) The fat of the ischiorectal fossa is entered and the incision deepened until the levator muscles are identified and incised well lateral to the bowel. (b) The perineal surgeon enters the supralevator compartment anteriorly in the midline. Only the anterior pillars of puborectalis remain to be divided. ⏎

is hooked around them and they are divided as far forwards as possible. During the final anterior dissection, delivery of the specimen out through the perineal wound may be helpful.

Anteriorly in the female patient, the plane between the vagina and the rectum is difficult to find, and follow, and part of the posterior wall of the vagina is often excised with the specimen. In anterior tumours, this is a safer strategy oncologically.

Small bowel loops will tend to fill the empty pelvis, and late adhesion obstruction can be troublesome. The caecum can be mobilised and allowed to drop into the pelvis to exclude the small bowel and reduce this complication. Alternatively, the uterus will often lie retroverted following an abdominoperineal rectal excision and will naturally fill some of the pelvis. Some surgeons favour mobilising the omentum on a left gastroepiploic pedicle to bring it into the pelvis. Opinion is divided on the desirability of attempting to close the pelvic peritoneum, as closure may create a dead space below it. The problem of a dead space will be reduced if the fatty margins of the ischiorectal fossa can be drawn together with a few absorbable sutures around a vacuum drain, but this may not be possible after a wide resection. Finally, the perineal wound is closed.

Variations A wide clearance of the perineal fat and skin may be necessary for an advanced tumour. Many of these patients have now routinely had preoperative radiotherapy or chemoradiotherapy, and there is substantial morbidity associated with delays in perineal wound healing. The wide surgical clearance may also predispose the patient to the development of a late perineal hernia. A flap, to bring well-vascularised muscle and skin into the perineum, may improve wound healing (see Chapter 5). Rectus abdominis and gluteus maximus are both suitably placed for use in the perineum. The former is recommended when the perineal dissection has been performed without turning the patient, but a gluteus maximus myocutaneous rotation flap, raised either unilaterally or bilaterally, may be more appropriate when the perineal dissection has been performed in the prone jackknife position. The involvement of a plastic surgery colleague is recommended.

LOCALLY ADVANCED RECTAL CANCER

Symptoms from an advanced locally invasive pelvic malignancy, whether a primary tumour or a recurrence after surgery, can be difficult to control, particularly in patients who are not terminally ill from metastatic disease. A small proportion of patients with locally invasive primary tumours, or recurrent pelvic malignancy confined to the pelvis, can be treated with curative intent by pelvic exenteration, but, for most patients, pelvic exenteration is not a curative option. Radiotherapy can have an important palliative role. An end colostomy will divert the faecal stream away from a malignant fistula into the bladder or vagina, but a loop colostomy is required if there is also luminal obstruction, or the closed rectal stump may 'blow'. Intraluminal stents can be considered for tumours above the mid rectum, but stents below this often increase local symptoms. Endoscopic debulking may decrease the discharge of blood and mucus and reduce tenesmus. Ureteric and venous stents can be considered for obstructed ureters or iliac veins, but the goals of palliation must not be forgotten in futile interventions, and pain from nerve invasion must be aggressively managed.

Due to the problems associated with advanced or recurrent pelvic disease, surgical excision of a resectable primary rectal tumour should be considered even if there is small-burden, yet unresectable, metastatic disease. However, careful selection is essential to optimise outcomes and quality of life.

Pelvic exenteration and sacrectomy

This radical and mutilating surgery should generally be considered only if all tumour can be excised. Anteriorly, the excision can include the bladder and prostate or, in a woman, the vagina, uterus and bladder. An end colostomy and urinary diversion, most commonly with an ileal conduit, will then be required (see Chapter 25). Posterolaterally, the excision plane can be outside the autonomic nerves, which are intentionally sacrificed. In selected patients with posterior bony invasion, a sacrectomy can be considered. This surgery should be performed only at centres with special expertise or the results will be disappointing with frequent major complications. A portion of the sacrum is excised with the specimen. Excision above S3 destabilises the pelvic ring, but this is occasionally justified. The sacrectomy, and mobilisation of the tumour from below to remove it *en bloc* with the sacrum, is performed with the patient in a prone jack-knife position. Abdominal access is required for mobilisation from above and for the urinary diversion. Either the patient is turned during surgery or the procedure is performed as two separate operations, sometimes on separate days, with the abdominal phase being undertaken the day before the final excision of the tumour through the perineum.[10]

LOCAL EXCISION OF SUPERFICIAL CANCER

A small cancer confined to the mucosa and submucosa (T1) can usually be removed by a local excision. There are two separate scenarios:

1. A rectal polyp has been removed and the histological report reports cancer in the polyp.
2. A polypoid lesion in the rectum has been identified and is what is called a significant polyp and early colorectal cancer (SPECC).

The concept of a SPECC was introduced to incorporate the difficulty in deciding if a polyp is benign or malignant and for instances in which the true nature of the lesion can only be confirmed when the lesion has been completely excised and examined under the microscope.[11] SPECC lesions are generally more than 2 cm in size and careful decision-making is required prior to management. Superficial biopsies may be unrepresentative and techniques for local excision, such as transanal minimally invasive surgery (TAMIS) or transanal endoscopic microsurgery (TEMS), if available, should be considered to remove the lesion completely and safely for histological analysis. MRI of the rectum is generally recommended prior to excision to identify any radiologically visible nodes, although the accuracy of determining if nodes are benign or malignant is low. Nevertheless, it is best to do an MRI scan before excision, as an MRI scan after excision is more difficult to interpret.

Care is needed in local excision of low SPECC lesions, particularly in men, in whom incomplete excision of an anterior cancer, in the form of an involved deep margin, may require an abdominoperineal excision to ensure complete excision.

Detailed histological analysis of the excised specimen is crucial. Malignant invasion of the submucosa, either beneath a flat lesion or beneath the stalk of a polyp, carries a risk of lymph node metastases of 5–10%. T1 lesions that are poorly differentiated or invade deeply into the submucosa (Japanese Sm 3) carry a higher risk of nodal involvement compared with Sm 1 well-differentiated tumours. The decision as to whether or not to recommend a major resection is complex and difficult and must involve discussions with the patient on risks and benefits of major resection or surveillance. Age and fitness are important considerations, as the potential benefit of a more extensive resection must be balanced against operative mortality and morbidity.

Generally, local excision is recommended only for predicted or actual T1 lesions. Nevertheless, T2 and even T3 lesions may also be fully excised by local excision in some patients with a higher risk of involved nodes, but a local excision may be justified in patients in whom the risk of death from major surgery outweighs the risk of recurrence from undetected nodal deposits. Perineal and transanal operations, both conventional and with the TEMS technique, are considered in more detail in Chapter 15.

UNSTABLE MUCOSA

Ulcerative colitis

Patients with ulcerative colitis who develop a cancer should usually be considered for a total proctocolectomy, which includes a radical lymphadenectomy of the segment of mesentery related to the tumour. Cancers on a background of inflammatory bowel disease arise more frequently from flat areas of dysplastic mucosa, and regular endoscopic surveillance may not accurately identify and remove further precancerous lesions. However, if the index primary cancer is advanced or already has metastasised, a surgeon and patient will wish to avoid futile radical surgery with the difficulties of a permanent stoma or the uncertainties of a pouch when there are fears that a patient may have a limited life expectancy. A decision may therefore be made to limit the initial surgery to treatment of the malignancy by the principles of segmental colonic cancer surgery.

Familial adenomatous polyposis

Another condition with unstable colonic mucosa is familial adenomatous polyposis (FAP) and other related genetic predispositions to colonic polyps and cancer. Ideally, patients with this condition should be managed according to the protocols of specialist disease-specific centres, if referral to such a centre for surveillance and surgery is an option.

Patients with FAP are also at risk of upper gastrointestinal polyps and malignancies and intra-abdominal desmoid tumours. The polyps in patients with FAP are too numerous for total endoscopic polyp removal to be a practical long-term solution. The polyps usually become apparent around puberty, and at this stage a total colectomy and ileorectal anastomosis is the best compromise in these asymptomatic patients who are understandably reluctant to accept a proctectomy. Additionally, postponement of proctectomy and pouch construction in young women will increase preservation of optimum fertility.[12] Regular surveillance of the rectum and removal of all rectal polyps is continued through adolescence and early adult life. A proctectomy, with ileostomy or an ileoanal pouch, should, however, be considered by the fourth or fifth decade of life, as even with regular surveillance almost 30% will develop rectal cancer by the age of 60 years.

Sporadic synchronous and metachronous tumours

Some patients present with two separate cancers (synchronous) and some develop a second primary cancer (metachronous) after prior colectomy. Each tumour should be treated on its merits, and colonic and lymphatic resection should be a radical excision. Most surgeons are prepared to leave the remaining colon *in situ* in the absence of underlying colitis or FAP, but regular colonoscopic surveillance is imperative. However, a total colectomy and ileorectal anastomosis, or even a total proctocolectomy, should be considered in younger, fit patients.

POSTOPERATIVE ANASTOMOTIC LEAKS AND FISTULAE

Any colorectal anastomosis has a risk of leakage, and the risks are higher the lower the anastomosis. Thus, leakage rates after a low rectal anastomosis are on the order of 10–15% and, for this reason, many surgeons use a temporary defunctioning stoma in this scenario, especially if a patient has had preoperative radiotherapy or there are any concerns about the anastomosis. The management of an anastomotic leak depends on a number of factors, including whether it is an early or late leak, whether the leakage is from the large or small bowel and whether there is generalised peritoneal soiling, a localised collection or fistulation.

GENERALISED PERITONITIS

An anastomotic leak that presents with generalised peritonitis will require re-operation. When the diagnosis is suspected or confirmed at imaging, the patient should be resuscitated with intravenous fluids and antibiotics and emergency re-operation planned. At laparotomy, the peritoneal cavity is cleared of small bowel contents or feculent material by copious irrigation. A simple repair of a defect is seldom practical, as the tissues are friable and oedematous. In an ileal or ileocolic anastomotic leak, the safest management is to bring out an end ileostomy of the proximal end. The distal end can be closed over and left inside the abdomen or brought out as a mucous fistula adjacent to the ileostomy. The latter is safer and also simplifies any subsequent operation to restore intestinal continuity. In colocolic leaks, if the anastomosis is above the peritoneal reflection, the safest operation may be to detach the anastomosis fully and bring out the proximal end as an end stoma. The distal end is safest if brought out as a mucous fistula and, if the distal end can be brought out adjacent to the proximal stoma, this simplifies subsequent surgery to restore gastrointestinal continuity. Unfortunately, the distal end often has insufficient mobility to reach as a mucous fistula and instead is closed and returned to the peritoneal cavity. It is recommended to wash out a closed colonic stump that is to be left *in situ* to reduce the risks of stump blowout with further peritonitis.

Pelvic peritonitis

Pelvic peritonitis after a leak from an anastomosis following an anterior resection usually requires intervention, even if the peritonitis is initially confined to the pelvis. A re-operation should always be performed with the legs up to allow access to the anal canal. Treatment by taking down the anastomosis and forming an end stoma will almost certainly condemn the patient to a permanent colostomy, as any rejoin at a very low level is difficult and subsequent bowel function is almost invariably poor. A better alternative is to select an area of the transverse colon that is suitable for a loop colostomy. A catheter is inserted though a colonic incision (colotomy) for a washout of the distal colon. A proctoscope is inserted and the effluent is drained through the anal canal; washing is continued until the distal colon is empty. The colotomy is then enlarged to create the defunctioning loop colostomy. No further faecal material should then reach the disrupted anastomosis. If the anastomosis is partially intact, healing should occur and it should be possible to close the stoma 6–12 months later.

A rectal contrast study should be performed before closure to confirm healing of the anastomosis and no residual connection with a pelvic abscess. Unfortunately, the subsequent bowel function is still often impaired.

Sealed leaks

A leak may seal and present as a localised intraperitoneal collection with an associated ileus or small bowel obstruction. Conservative management with intravenous fluids and antibiotics will often suffice, but drainage of the collection may become necessary. A localised collection of infected gastrointestinal contents, walled off within the peritoneal cavity, may track into another viscus or to the exterior via the vagina or the surgical wound. When there is still a persistent leak from the anastomosis into the walled-off collection, which is draining externally, a fistula will have been established.

Wound fistulae

A wound fistula usually presents initially as a wound infection. It then becomes apparent that intestinal contents are draining through the wound. Immediate repair is not advisable and the initial management is maintenance of fluid and electrolyte balance, drainage of infection, maintenance of nutrition and protection of the abdominal skin from intestinal juices. Ultrasound scans, or CT if available, will show whether there is an intra-abdominal collection deep to the wound and, if there is a large collection, drainage of this should be improved by enlarging the defect. If the patient has bowel actions or a more distal stoma effluent continues, there is still continuity of the gastrointestinal tract, and the fistula track may close spontaneously if there is no distal obstruction. Parenteral nutrition may be needed in some cases, but patients with a low-output colonic fistula can often continue to maintain oral nutrition.

A *persistent fistula* will require surgical repair and often a major laparotomy. A delay of 6–12 months, if possible, facilitates safe dissection and repair.

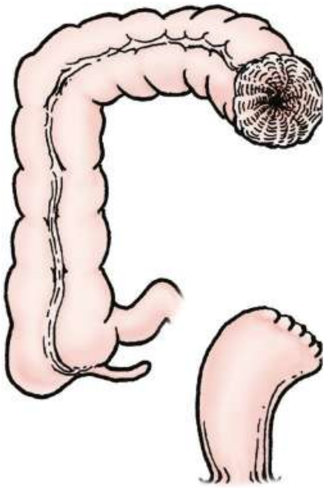
Rectovaginal fistulae

A rectovaginal fistula may occur after the breakdown of a pelvic anastomosis. If the bowel was not already defunctioned prophylactically, a laparotomy and defunctioning stoma is generally required to facilitate healing. The fistula is then repaired, as discussed in Chapter 15.

FORMATION OF STOMAS

An enterocutaneous stoma can be considered a controlled iatrogenic fistula.[13] A stoma may be fashioned as an alternative outlet to the gastrointestinal tract after excision of all distal bowel or when restoration of continuity after a resection is contraindicated (Figure 14.21). Stomas are also used as a temporary or permanent diversion of the faecal stream from distal pathology or a healing anastomosis. A temporary stoma is commonly a loop stoma that can be closed without a major laparotomy when it is no longer required. An end stoma is preferable when permanence is anticipated. A loop stoma may be left as a permanent stoma, but is more prone to complications. An *end stoma* has a single opening from the proximal bowel, and the epithelial continuity is between the skin and the whole circumference of the bowel mucosa (see Figures 14.22 and 14.24). A *loop stoma* is formed by an enterotomy on the antimesenteric border of a loop of bowel that has its continuity maintained by an intact mesenteric border. There are two openings: one into the proximal bowel and one into the defunctioned distal bowel. The epithelial continuity is between the skin and the mucosa around the edge of the enterotomy (see Figures 14.23 and 14.25).

Colostomies and ileostomies are the common enteral stomas. Colostomy effluent is ‘faecal’ and intermittent. A sigmoid colostomy may only empty once daily with formed stool and is the easiest to manage, whereas an ileostomy may empty continually. Ileostomy effluent is usually thickened



14.21 A terminal colostomy. An end stoma has been formed and the rectum has been closed and left *in situ*. This is a satisfactory solution when there is no distal obstruction. When there is a distal obstruction, either a loop stoma should be formed or the distal end should be brought out as a separate mucous fistula. ⏎

small-bowel contents, and patients often prefer this, as it is 'non-feculent' and usually less malodorous. However, dehydration may be a problem, especially in older patients, particularly in the early weeks when effluent volumes are highest. A transverse colostomy is the least popular stoma, as it produces a large volume of soft, offensive faecal effluent. It does, however, have a useful role as a temporary defunctioning loop stoma. Good stoma management is essential if the patient's preoperative quality of life is to be regained. The expertise of stoma nurse specialists, together with advances in appliances, have greatly reduced the problems of leakage and skin excoriation. The first essential, however, is for the surgeon to site the stoma optimally and to fashion it correctly. If at all possible, the preferred site for a stoma should be marked preoperatively by the stoma therapist in conjunction with the patient. An apparently ideal site in a patient on the operating table may be buried in a skin crease when he or she sits, or be out of sight and dependent on the undersurface of a protuberant abdomen when standing. The stoma should be through an area of smooth flat skin so that a good seal with an appliance can be achieved. The vicinity of the umbilicus and abdominal scars should therefore be avoided.

A stoma is usually brought out through the rectus sheath a few centimetres either above or below the umbilicus. More lateral stomas were thought to be associated with a higher incidence of incisional herniae, but this is uncertain. A disc of skin and subcutaneous fat is excised. It is inadvisable to bring a stoma out through a wound, as the incidence of wound infection, parastomal herniation and problems with appliance fixation to irregular scarred skin are all increased.

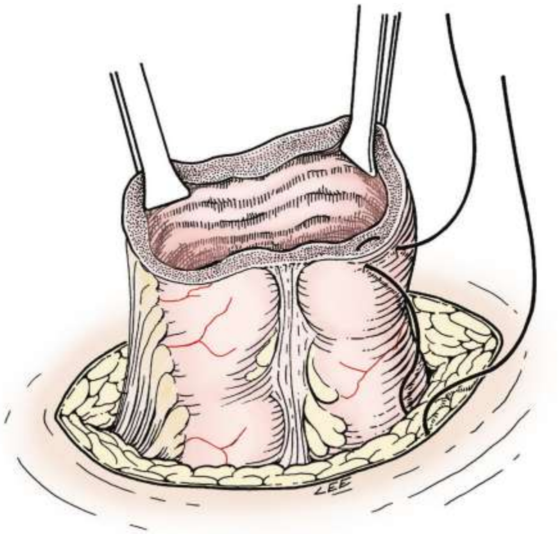
LEFT ILIAC FOSSA END COLOSTOMY

This stoma is formed after a resection that leaves no distal bowel to which an anastomosis can be made or when a restorative procedure is contraindicated. It is, therefore, the final step in an abdominoperineal excision or a Hartmann's procedure. An end left iliac fossa colostomy may also be used as the permanent diversion of a rectum irretrievably damaged by tumour, inflammation or trauma, and as a final solution for faecal incontinence or a rectovaginal fistula. The rectum is closed and left *in situ* (Figure 14.21). However, this is an unsuitable operation if there is distal obstruction or the prediction that this will occur later, as the rectal stump may distend with mucus and the closure disrupt with resultant peritonitis. Instead, either a loop stoma should be used or, in addition to the end colostomy, the distal defunctioned end should be brought out as an additional stoma, which is described as a *mucous fistula*.

Adequate length is essential in creating the stoma or retraction will occur, and allowance must be made, particularly in obese patients, for the anterior abdominal wall protuberance that will occur when standing. Postoperative distension from ileus will also increase any tension. If the bowel division has been high in the descending colon, mobilisation of the colon by incision of the peritoneum lateral to the bowel will increase the length of colon available, and can be extended to a full mobilisation of the splenic flexure if necessary.

The optimal site on the colon for the stoma is chosen and the bowel is divided with a mechanical linear stapling device. This has the advantages of closing the distal end definitively and producing a temporarily sealed proximal end for delivery through the abdominal wall without the extra bulk of a clamp. (If such a device is not available, the distal end is closed with sutures and a small clamp is used to seal the proximal bowel.)

The disc of skin and subcutaneous fat is excised at the chosen stoma site and a horizontal or vertical incision is made through the anterior layer of the rectus sheath. The rectus muscle is split and the incision is extended through the posterior sheath and the parietal peritoneum. The size of the opening is difficult to judge; it should be snug, but not tight, around the bowel. Too small an abdominal fascia incision produces a dusky oedematous stoma, while too large an incision predisposes to a parastomal hernia. It is



14.22 An end colostomy. The closed end of the colon has been brought through the abdominal wall and trimmed. Skin–mucosal apposition is then achieved with interrupted absorbable sutures. This is illustrated here with a suture passed extramucosally in the bowel and subcuticularly in the skin; this may be a superior refinement to the simpler suture described in the text. ⏎

easy to damage the inferior epigastric artery within the rectus muscle. At open surgery, the arterial pulsation can be palpated from within so that an incision through the vessel can be avoided. If cut, the ends retract and are difficult to locate. When injury occurs and there is a separate laparotomy incision, deep suture ligations placed from within, a few centimetres above and below the stoma incision, will include the severed vessel, and is the easiest method of control.

Babcock forceps are introduced through the stoma incision to hold the proximal bowel end and guide it gently through the abdominal wall to the skin. The main incision, or laparoscopic ports, is/are then closed before the stoma is opened. The few millimetres of colon that are crushed in the clamp, or held with staples, are excised. Bleeding points may have to be coagulated, and the free edge of the bowel is then sutured to the skin around the defect with fine interrupted absorbable sutures. Each bite should include the full thickness of bowel wall and a bite of skin, although it is important to deliver the needle close to the skin edge (Figure 14.22).

If no resection is planned, the surgeon will wish to avoid a major laparotomy. It may be possible to perform a *trephine stoma*, in which a loop of mobile sigmoid colon is delivered through the definitive incision for the stoma. However, this is not always possible and it may be dangerous if there is tension due to inadequate mobilisation. The colon is delivered outside the wound, the bowel is divided and the sealed distal end is replaced. It is imperative that, at this stage, the surgeon is sure which end is the proximal bowel and which is the distal bowel. When access is too limited for certainty, insufflation of the rectum with air from below will confirm the distal limb. The limited division of the sigmoid mesentery, to allow sufficient separation of the ends without devascularisation, is also more difficult with a trephine technique. Injury to the inferior epigastric vessels is both more difficult to avoid and more difficult to treat when there is no separate abdominal incision. An increasingly popular alternative to the simple trephine stoma technique is to combine it with a laparoscopic mobilisation of the sigmoid loop. The mobilisation is completed and the pneumoperitoneum released, while the sigmoid loop or sealed end is held just under the site of the stoma by an instrument retained within a port site. Identification and delivery of the colon through the small trephine incision are thus much easier.

When laparoscopic facilities are unavailable and a simple trephine technique is not straightforward, a small laparotomy to mobilise the sigmoid is safer. A lower abdominal midline incision is the approach usually recommended, but a low left iliac fossa oblique muscle-cutting incision has the advantage of giving better access to the peritoneum lateral to the sigmoid colon. This incision can be placed so that it will lie outside the fixation of the appliance. It must be below, lateral to and at a sufficient distance from the skin mark of the proposed site of the stoma.

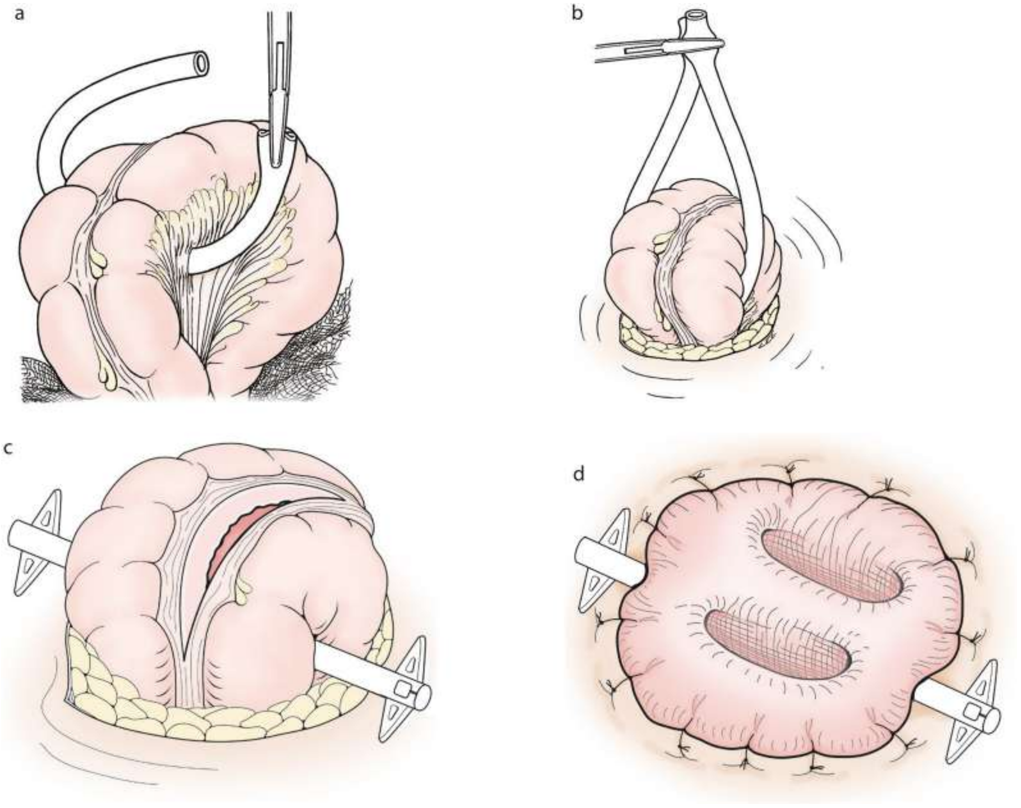
LEFT ILIAC FOSSA LOOP COLOSTOMY

A left iliac fossa loop colostomy is the appropriate stoma when there is a rectosigmoid obstruction and no resection is planned, as it can also decompress the distal colon immediately above the obstruction. If, however, a later resection is planned, a more proximal colonic stoma may be preferable. The pelvic colon is mobilised as for the formation of an end colostomy. The bowel is not divided but brought out as a loop in a similar manner to the fashioning of a transverse loop colostomy.

TRANSVERSE LOOP COLOSTOMY

A transverse loop colostomy is a temporary stoma and was traditionally the standard emergency treatment of a left colon obstruction. It may still have a place in this situation, but a primary resection or colonic stent, if feasible, is now the preferred option. The defunctioning loop colostomy is most often indicated as a temporary diversion to protect a left colon anastomosis. Coloanal anastomoses are particularly vulnerable to anastomotic leakage, and some surgeons routinely defunction with a loop stoma. Surgeons were divided in their preference for either a loop transverse colostomy or a loop ileostomy as a temporary measure, but most now generally favour an ileostomy. The colostomy is less pleasant for the patient to manage and is probably associated with more wound infections and incisional herniae after closure. These disadvantages may be offset by a reduced likelihood of early fluid and electrolyte loss and a lower long-term risk of late adhesion obstruction. In addition, if there were a leak, the more distal stoma would potentially provide a better defunction of the anastomosis and reduce contamination from the leak.

A suitable site in the proximal transverse colon is selected that will reach the abdominal skin without tension. The greater omentum is separated from this portion of the colon and a pericolic window is made close to the bowel wall. A pair of artery forceps is passed through the window to grip a soft catheter, which is guided through (Figure 14.23a). A stoma incision is then made in the same fashion as for a left iliac fossa colostomy, but in the right hypochondrium. Forceps passed through the stoma incision can grip the catheter and guide the loop of colon through the abdominal wall while it is eased through from inside (Figure 14.23b). The main incision is then closed. If a colostomy bar is to be used, it is guided through the mesenteric window by inserting one end, which has been swivelled to lie in line with the bar, into the open end of the catheter. The catheter is removed and the end of the bar swung back to right angles (Figure 14.23c). The bar is removed about 10 days postoperatively and, until then, provides support to the colonic loop, preventing retraction. Severe tension



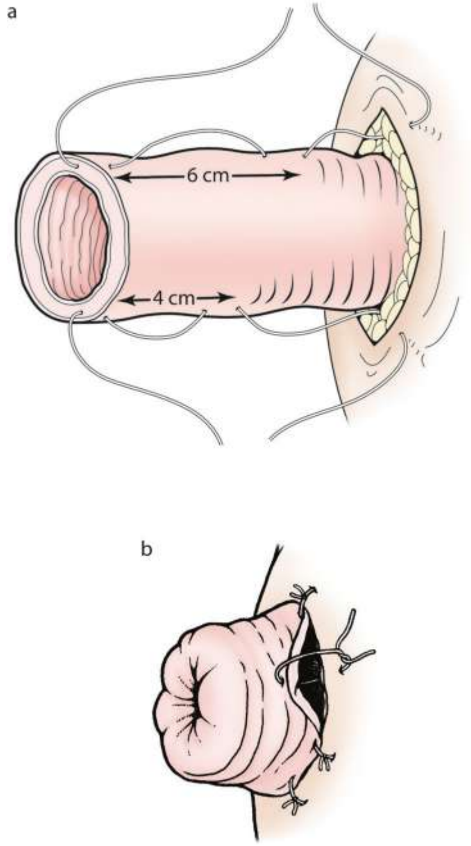
14.23 A loop colostomy. This is illustrated with a colostomy bar, which many surgeons now feel is unnecessary on the grounds that, if there is no tension, it is of no value and argue that it merely causes difficulty with early appliance fixation and may cause additional scarring, which could make subsequent closure more difficult. (a) A pair of artery forceps has been passed through a mesenteric window close to the bowel and is now drawing a catheter through. (b) A pair of artery forceps has been passed into the abdomen through the prepared stoma site and the ends of the catheter grasped. The bowel is gently delivered to the exterior. (c) The colostomy bar has been guided through the mesenteric window by its insertion into the open catheter end. A longitudinal incision is made in the colon. (d) The bowel edges are folded back to the skin edges and skin–mucosal apposition is achieved with interrupted sutures, except where the stoma bar emerges. ⏎

will, however, result in the bar ulcerating through the bridge of intact bowel wall and will not prevent retraction in this situation. The main abdominal wound is now closed. The stoma is then opened and sutured to ensure skin–mucosal apposition and healing without stenosis. A longitudinal incision along the taenia can be made with a scalpel and scissors or with diathermy, with care being taken to avoid injury to the opposite wall of the bowel (Figure 14.23c). The bowel is then opened and the cut edge of the bowel is apposed to the skin edges of the colostomy incision with interrupted absorbable sutures in the same fashion as when suturing an end colostomy. Skin–mucosal apposition is only deficient where the stoma bar emerges (Figure 14.23d).

End ileostomy

This is the stoma created at the completion of a total colectomy. The optimal stoma site, high in the right iliac fossa, should have been marked preoperatively.

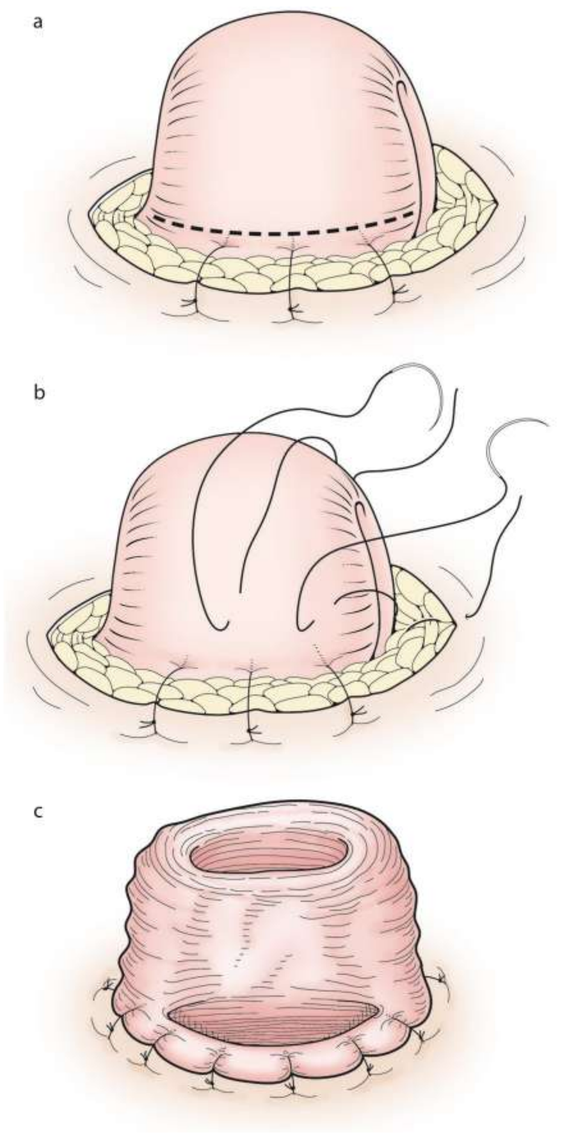
At surgery, a disc of skin is excised and an incision is made through the abdominal wall as described for an end colostomy. The terminal ileal stump is then drawn through the abdominal wall in a similar manner, with care being taken to avoid rotation. There will inevitably be some mesentery drawn through with the ileum, as complete division of this from the bowel will result in an ischaemic stoma. Skin–mucosal apposition is again achieved with interrupted absorbable sutures, but a 'spout' to the stoma should be created so that the more liquid stoma effluent drops into the bag, beyond the flange of the appliance. A flush ileostomy can result in excoriated skin due to leaks as the flange separates from the skin. A spout of 2–3 cm is sufficient and is fashioned from the terminal 6 cm of the bowel, which has been drawn out through the abdominal wall. The spout is created by an eversion manoeuvre, in which the first four skin–mucosal apposition sutures include a seromuscular bite of more proximal bowel wall (Figure 14.24a). Care must be taken not to include mucosa in this seromuscular bite, as it may create a fistula at the stomal edge. When placing these sutures, care must also be taken to avoid injury to the mesentery of the bowel. The mesentery often distorts the stoma initially, but, after eversion, it is normally no longer a problem. These four sutures are left untied until all are in place and then, as they are tied, the stoma everts. The stoma must sometimes be gently eased into position, as complete reliance on the sutures to achieve eversion may cause them to tear through the bowel. The stoma should ideally point slightly downwards, and this can be achieved by placing the superior everting suture with its seromuscular bite 6 cm from the free edge, an inferior suture with a bite at 4 cm and two lateral sutures with bites at 5 cm. Precise measurements of the distance of these bites from the open bowel end make the creation of an optimal stoma easier. After eversion, a further skin–mucosal apposition suture is placed between each of the everting sutures (Figure 14.24b).



14.24 An end ileostomy. (a) Lateral view of the stoma as the everting sutures are inserted. These sutures include a seromuscular bite of the ileal wall between the bites of skin and bowel edge. To produce a 2.5 cm spout, facing slightly downwards, these seromuscular bites should be 6 cm from the end of the ileum superiorly and 4 cm inferiorly. Laterally, they should be at 5 cm. (b) The everting sutures are tied, the spout is formed and skin–mucosal apposition is completed with additional sutures. ⏎

Loop ileostomy

A loop ileostomy is the stoma most frequently used to defunction an empty colon in order to protect a vulnerable distal anastomosis. The stoma incision is prepared and Babcock forceps are passed through the stoma incision to hold the terminal loop of ileum and draw it gently through to the exterior. Before closure of the main laparotomy wound or laparoscopic ports,



14.25 A loop ileostomy. (a) Three sutures are placed between the skin edge and the seromuscular coat of the distal limb prior to closure of the main wound. This manoeuvre prevents any rotation of the loop and confusion as to which is the proximal and which is the distal limb. (b) An incision has been made a few millimetres above the three seromuscular skin apposition sutures. The superior and the first lateral eversion sutures are in place, but untied. (c) As the sutures are tied, the stoma everts as a spout. Viewed from below, the distal bowel opening is visible, flush with the skin. ⏎

the loop is orientated so that the distal limb is inferior, and three sutures are placed apposing the unopened wall of the distal loop to the skin edge (Figure 14.25a). After the main wound is closed, the stoma is opened by an incision 2–3 mm above the three sutures. The incision is extended to just over half the diameter of the distal limb. Eversion sutures are then placed superiorly and laterally, exactly as for a terminal ileostomy (Figure 14.25b), and the proximal limb of the stoma is drawn out as a spout (Figure 14.25c).

STOMA COMPLICATIONS

Some patients have a trouble-free stoma, while others have recurrent problems that may need further surgery.

RETRACTION AND STRICTURE

Retraction of a stoma in the first 2 weeks is often in conjunction with separation of the skin-to-mucosa suture line. It is most commonly caused by excessive tension on the afferent bowel, and therefore no local operation on the stoma will be helpful. Relaparotomy is indicated if there is cellulitis around the stoma, indicating the escape of bowel contents into the abdominal wall, or if signs of peritonitis indicate escape into the peritoneal cavity. Re-operation will be difficult, as a new stoma will have to be fashioned with bowel, which will be more friable to handle, and problems of tension will be increased by postoperative oedema. Fortunately, more minor degrees of early retraction can usually be managed conservatively, although a stricture may develop as healing occurs by secondary intent.

A late retraction of a colostomy, often with an associated stricture, or an ileostomy that has lost its spout can usually be corrected by a local refashioning operation. The skin immediately adjacent to the stoma is incised circumferentially and the stoma is mobilised as for a stoma closure (see ‘Closure of loop stomas’ later in this chapter) and refashioned. A relaparotomy can be avoided unless adequate length cannot be obtained without deeper mobilisation. An intermittently retracting ileostomy can be fixed in position by linear stapling at two or three positions around the circumference. One blade of the stapler is introduced into the ileostomy and the other blade is on the outside. It is important that the linear cutting stapler is not used in error!

Conservative management of a stricture with dilation is sometimes successful but, more often, revision surgery is required. A stricture at the mucocutaneous junction, without stoma retraction, can be solved very simply by a minor operation under local anaesthesia, as minimal dissection is required. The skin is incised circumferentially just outside the stenosed orifice and the stoma is then mobilised down to the abdominal fascia. The stenosed mucocutaneous junction is trimmed from the end of the stoma and a fresh apposition of skin and bowel is secured with interrupted sutures. At this stage, the surgeon often realises that the incision around the stenosed stoma has removed too large a disc of skin.

PROLAPSE

Prolapse of an end colostomy can be dealt with locally by a circumferential skin incision. After minimal dissection, the redundant bowel is drawn out and amputated. The new end is sewn to the skin edges. Unfortunately, recurrence is common. A prolapse is sometimes associated with an incisional hernia and is then best managed by resiting of the stoma (see 'Closure of loop stomas' later in this chapter). Colostomy prolapse is more common in loop stomas and can usually be managed conservatively until closure can be safely undertaken. If closure is not an option, full mobilisation of the stoma will allow division of the loop. The distal end, which is often the end that is prolapsing, is then closed and dropped back into the abdomen. Proximal redundant bowel can be excised before resuturing the bowel to the skin edges. This is, of course, only an option when there is no distal obstruction.

Prolapsing end ileostomies are uncommon and any local excision procedure is likely to offer a temporary solution only because of the mobility of the small bowel. To prevent prolapse, the bowel adjacent to the stoma must be fixed to the parietal peritoneum over a distance of about 10 cm with non-absorbable sutures. The old technique of extraperitoneal routing of an ileostomy to obliterate the lateral space produced a similar fixation of the terminal ileum.

PARASTOMAL HERNIAE

Parastomal herniae are difficult to treat, but strangulation, although possible, is fortunately uncommon. Surgeons are therefore often reluctant to advise any revisional surgery, especially if the hernia is easily reducible. However, patients are often troubled with both the difficulty in securing the appliance and the prominence of the stoma appliance showing through their clothes when it is secured to the summit of a protruding hernia. Patients may also complain of abdominal wall discomfort on exertion or colic from small bowel loops within the sac. Occasionally, a specially fitted corset will be of value.

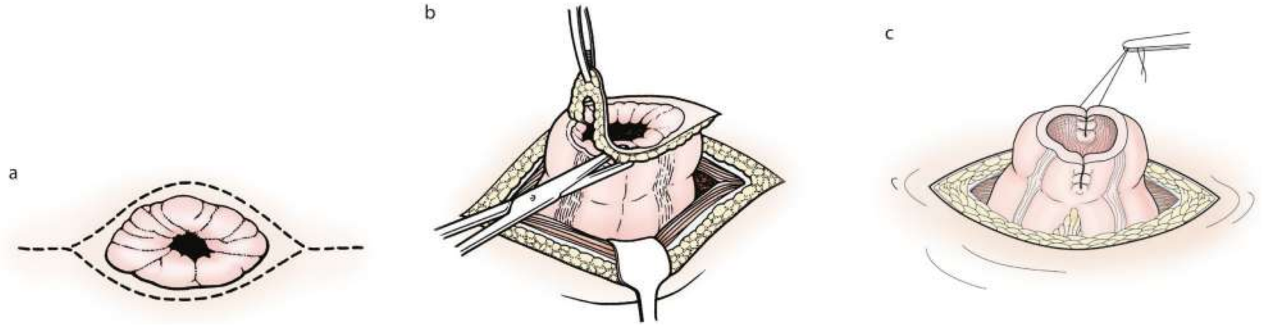
Local mobilisation of the stoma and excision of the hernial sac, followed by one or more sutures placed to narrow the abdominal wall opening, and, finally, resuturing of the bowel end to the skin is simple, but usually fails. The addition of mesh reinforcement has traditionally been avoided because of concern over mesh infection, but this risk has probably been overestimated.[14] The most satisfactory alternative is often to reopen the abdomen and resite the stoma through a separate area of abdominal wall. The stoma and the associated hernia can be dissected from both within and outside the abdomen, the hernial sac is excised and the old stretched stoma defect is closed completely.

Resiting may be impractical if the abdomen is extensively scarred or if there is an insufficient length of bowel to reach another abdominal site. A third alternative is to approach the parastomal hernia from outside, but through an incision placed well lateral to the stoma itself.[15] Incisions on both sides of the stoma may improve access to the sac for dissection, reduction and closure. The stoma is excluded from the operative field with a skin adhesive covering and the skin–mucosal apposition of the stoma is left undisturbed. Contamination of the abdominal wall defect can thus be avoided and a mesh may be used to encircle the bowel at the level of the fascia. Laparoscopic repair can also avoid contamination. The use of biological meshes, although expensive, reduces the concern over mesh infection. Prophylactic mesh insertion, when a stoma is created, does seem to reduce the incidence of parastomal herniation.[12]

CLOSURE OF LOOP STOMAS

A temporary stoma, which has protected an anastomosis, may be closed as soon as the anastomosis is soundly healed. Early closure, at around 2 weeks, is practised by some surgeons but is technically more difficult at this stage. A delay of 6–8 weeks allows the stoma to mature and the planes around the stoma to become better defined. The additional wait will also allow the patient to regain nutritional and immunological status after a major operation, and will also reduce the risk of thromboembolic complications. However, the patient has to learn to manage the stoma in order to return home.

An elliptical incision allows linear closure of the skin (Figure 14.26a), but some surgeons prefer a circular skin incision that cicatrices to a circular scar. The skin incision is deepened into subcutaneous fat and the bowel wall is identified. Two artery forceps, placed on the skin to be excised, provide useful counter-retraction while the assistant retracts the skin and subcutaneous fat. The plane is followed between the bowel and the subcutaneous fat and then between the bowel and the abdominal wall until the peritoneal cavity is reached. The assistant retracts progressively deeper as the dissection continues. The correct plane is easier to identify adjacent to the bowel than adjacent to the mesentery, and the plane will be particularly difficult around the scarring from a colostomy bar, if a bar was used. If the surgeon dissects in one



14.26 Closure of a loop stoma. (a) Elliptical skin incision. (b) After full mobilisation of the stoma, the mucocutaneous junction of the colostomy is excised. (c) The bowel is then closed transversely.

area until the plane becomes difficult, and then moves to another area, again until difficulty is encountered, generally on returning to the previous area the dissection is now easier, as mobility has increased. Some difficulty is occasionally encountered deep in the abdominal wall dissection, as dissection may enter an extraperitoneal plane rather than entering the peritoneum. After the peritoneal cavity is entered, a finger, introduced and swept around the fascial defect, can identify further bands to be divided. Adhesions can be broken down with the finger, but great care must be taken not to tear a loop of adherent small bowel. The stoma can now be lifted further out into the wound, and the dissection to free the stoma has also prepared the abdominal wall for a satisfactory closure of the fascia. If extreme difficulty is encountered, or damage has occurred to adjacent bowel, the surgeon must extend the wound to convert to a mini-laparotomy. Alternatively, a separate midline incision is made.

A *colostomy stoma* is prepared for closure by excision of the mucocutaneous junction (Figure 14.26b). Difficulties are more often encountered if too little rather than too much is trimmed, as the bowel wall is still distorted and thickened. Haemostasis may be required, and the colonic wall defect is then closed transversely (Figure 14.26c) with interrupted extramucosal sutures, as described in Chapter 7.

An *ileostomy stoma* cannot be closed until the eversion has been reversed. After full mobilisation of the stoma, as described above, the skin adherent to the eversion is incised to gain access to the plane between serosal surfaces, which is then developed until the alignment of the original enterotomy has been restored (see Figure 14.26). The remaining mucocutaneous junction is excised and the defect is closed as for a colostomy. It is easy to damage the bowel wall where the plane is first developed for reversing the eversion. A minor injury can simply be sutured, but if it is more significant, a formal resection of a short segment of small bowel and re-anastomosis is safer, and this can be performed without enlarging the incision.

An alternative to an end-to-end, partial circumferential, sutured anastomosis is a side-to-side stapled anastomosis. This is more suitable for closure of a loop ileostomy than for a colostomy. The initial mobilisation of the stoma and trimming of the mucocutaneous junction are identical. A linear cutting stapling device is then introduced so that one blade lies within the efferent bowel and one in the afferent bowel. A finger is swept between the blades from one side to the other, before the instrument is closed, to displace the mesentery out of the staple line. The device is fired to create the anastomosis. The device is then withdrawn, reloaded and fired again across the two open bowel ends to close them.

After completion of the bowel closure, the loop is dropped back into the peritoneal cavity. If replacement is difficult despite good relaxation, a small lateral release of the abdominal fascia allows replacement without endangering the suture line by excessive pressure. Incisional herniae are common through these wounds, and meticulous abdominal wall closure to include the anterior rectus sheath fascia is essential. This is difficult through the small skin incision and is easiest to achieve by placing three or four interrupted sutures, which are left untied until all sutures are in place. If an elliptical incision has been made, the wound may be closed primarily with interrupted or even subcuticular sutures. A drain to the subcutaneous fat has advantages in the obese patient. A pressure dressing to the wound may also decrease the incidence of wound infection by reducing the formation of a contaminated seroma or haematoma in the subcutaneous fat. Circular incisions are usually left open to heal by secondary intention, but a purse-string subcuticular suture may be used to reduce the size of the wound and subsequent scar.

Closure of an end stoma requires identification of the distal bowel end. If this has been secured just beneath the stoma or brought out as an adjacent mucous fistula, a dissection followed by an anastomosis may be possible through a small local incision. More often, unfortunately, the distal bowel can only be identified from within. If laparoscopy is unavailable, this will often require a full laparotomy.

Long-term complications of temporary stomas include incisional herniae, which are more common after the closure of a colostomy, and adhesion obstruction, which may be more common after a previous ileostomy.

SMALL BOWEL TUMOURS

Tumours of the small bowel are rare and account for less than 5% of all gastrointestinal malignancy. The most common tumour types are adenocarcinoma (30–50%) and carcinoid (neuroendocrine) tumours (25–30%), with gastrointestinal stromal tumours (GISTs) and lymphoma making up a smaller minority. Patients commonly present with symptoms of bowel obstruction, which often occurs at a late stage in the disease process, meaning the prognosis is poor. Less commonly, patients may present with rectal bleeding or anaemia. Diagnosis is most commonly made on CT scan, although MRI or capsule endoscopy may be used to identify small lesions that are not causing obstruction. The mainstay of treatment for small bowel adenocarcinoma is segmental small bowel resection with or without adjuvant chemotherapy. The specific management of carcinoid tumours, GISTs and lymphoma is discussed below.

CARCINOID TUMOURS

Carcinoid (neuroendocrine) tumours arise from the enterochromaffin cells, which are present throughout the gastrointestinal tract and may be either benign or malignant. A small benign carcinoid is most often encountered in an appendix that has been removed because of appendicitis. The tumour, rather than a faecolith, has obstructed the lumen and initiated the appendicitis. A small bowel carcinoid may cause obstructive symptoms and, at surgery, will be excised as a possible small bowel carcinoma. These tumours are frequently multiple and the whole small bowel must be carefully examined. Malignant carcinoid tumours have a pattern of spread similar to that of gastrointestinal carcinomas, but they are slower growing and a patient with metastatic carcinoid may remain in reasonable health for some years. Carcinoid tumours secrete 5-hydroxytryptamine (5HT) (serotonin) and other related active compounds, which are metabolised in the liver. When the systemic levels of these active compounds rise and the symptoms of ‘carcinoid syndrome’ develop, it indicates that the tumour is draining directly into the systemic circulation. Thus, it usually indicates liver metastases draining into the hepatic veins, but the liver can also be bypassed when there are tumour deposits in the retroperitoneal nodes. The flushing, diarrhoea and bronchoconstriction of carcinoid syndrome can be controlled with octreotide (which blocks 5HT release), but resection of liver secondaries should also be considered, especially as this is one of the few situations when even partial removal of liver secondaries may lead to a significant improvement in symptoms and prognosis.[5]

GASTROINTESTINAL STROMAL TUMOURS

GISTs are mesenchymal tumours that can occur throughout the gastrointestinal tract; they were previously classified as leiomyomas and leiomyosarcomas. Presentation is often with gastrointestinal haemorrhage or an acute abdominal emergency,[8] and the diagnosis may only be made at emergency laparotomy. The clinical behaviour of GISTs is very varied, but they should all be regarded as potentially malignant. In common with other sarcomas, they recur locally if the margins of excision have been inadequate. GISTs metastasise via the bloodstream but, as lymphatic spread is not an issue, surgery is focused on wide local excision rather than lymphadenectomy. Chemotherapy has little to offer and radiotherapy can seldom be deployed without unacceptable toxicity at dosages that might be curative. An increased understanding of their origins, probably from pacemaker cells of the gut, has led to the development of the tyrosine kinase inhibitor imatinib (Glivec®) as an effective treatment for irresectable disease.

LYMPHOMA

A lymphoma can occur within any mesenteric or retroperitoneal lymph node. In addition, a lymphoma can arise from the lymphoid tissue in the gut wall, classically producing a thickened area of small bowel, which may ulcerate or obstruct. A lymphoma may also form the apex of an intussusception. Although the definitive treatment is medical, the initial surgical presentation with a mechanical complication, haemorrhage or inflammation often necessitates a resection, which also provides the tissue for histological diagnosis.

PSEUDOMYXOMA PERITONEI

Pseudomyxoma peritonei is a rare tumour, generally originating from a perforated mucinous tumour of the appendix, presenting as mucinous ascites secondary to peritoneal surface malignancy. The mucinous ascites may fill the peritoneal cavity. The visceral and parietal peritoneal surfaces have adherent tumour masses consisting of cysts of trapped jelly, and tumour masses form in the omentum, around the spleen and in the pelvis. Classical pseudomyxoma is a mucinous adenoma or low-grade mucus-producing adenocarcinoma, usually originating from a perforated appendiceal tumour, which is, at best, described as a ‘borderline malignancy’. The disease disseminates and progresses locally but generally does not metastasise via lymphatics or the bloodstream. The most common site of origin is from an adenoma of the appendix, and it is only after rupture that peritoneal dissemination occurs.[7] In women, many cases are incorrectly classified as ovarian cancers, as large deposits grow on the ovaries, and there can also be confusion with frankly malignant mucinous adenocarcinomas of the colon. Worthwhile long-term palliation, and even cure, is possible with an extensive surgery entitled cytoreductive surgery (CRS), which involves peritonectomy procedures and resection of involved organs combined with hyperthermic intraperitoneal chemotherapy (HIPEC).

The surgery is specialised and involves a radical omentectomy, inside the gastroepiploic arcade, and extensive stripping of involved parietal and visceral peritoneum by diathermy dissection, combined with the excision, if necessary, of extensively encased organs such as spleen, gallbladder, stomach and segments of colon. Fortunately, the small bowel and its mesentery is relatively spared. Specialised centres have been established for the surgical management of these tumours, and referral is indicated. If this tumour is suspected at laparotomy, histology should be obtained, preferably by an omental biopsy. Any partial debulking procedure or hysterectomy should be avoided, as the tumour will seed onto any raw, non-peritonealised surfaces exposed by the surgery. The resultant encasement of vital structures, such as ureters, makes subsequent complete cytoreduction more hazardous. Primary peritoneal mesothelioma poses similar surgical challenges, but the prognosis is worse.

RETROPERITONEAL SARCOMAS

Retroperitoneal sarcomas are generally more aggressively malignant than GISTs. They present late, as there is no early gastrointestinal obstruction or haemorrhage. Surgical excision is often combined with radiotherapy, which can be targeted to give adequate doses to the tumour while avoiding excessive exposure to the small bowel.

DESMOID TUMOURS

Desmoid tumours are borderline malignant soft tissue tumours that can occur both in the abdominal wall and intra-abdominally. They are common in patients with FAP. Desmoid tumours do not metastasise but are locally aggressive, with a propensity for recurrence after resection. The more common abdominal wall tumours are seldom life threatening, but the intra-abdominal lesions, which are most often located within the mesentery, may cause small bowel complications. Management decisions are difficult, as the proximity of the tumours to mesenteric vessels renders surgical excision technically difficult, with a high morbidity and mortality.[9] The natural history of the lesion, if left *in situ*, is very variable and may be modified by the administration of tamoxifen, non-steroidal anti-inflammatory agents or cytotoxic chemotherapy. These tumours are best managed in specialised centres.

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Surgery of the anus and perineum

15

Mark Ranjan Jesudason and Neerav David Aruldas

Many patients present to the general surgeon with perianal complaints. Most will be found to have minor anal pathology not requiring surgery. However, all patients require careful assessment to exclude serious pathology. Many patients only require reassurance that the symptoms are not caused by cancer, but those with troublesome symptoms are most often managed with medical treatment or a minor procedure in the outpatient clinic. Those with defecatory problems or impaired continence will require careful assessment of their problem, but only a minority will benefit from surgery.

ANATOMY AND PHYSIOLOGY

An understanding of the anatomy and physiology of the anal canal is of utmost importance to any surgeon undertaking even the most minor anal operation, as overstretching of the sphincter muscles or partial division, whether inadvertently or in the treatment of a fissure or fistula, may have a deleterious effect on continence.

ANATOMY

The anal canal passes downwards, and backwards, for around 4 cm as a direct but narrower extension of the rectum to end at the anal orifice or *anal verge*. The anal verge is usually used as the reference point when measuring the height of any rectal or distal colonic lesion. Another important anatomical reference point is the anorectal angle, which can be determined both clinically and radiologically. This angulation in the anorectal tube is created by the puborectalis muscle sling, which is formed by the anterior most fibres of the levator ani, the main component of the muscular pelvic floor. The puborectalis muscle sling does not encircle the anus and is deficient anteriorly (Figure 15.1). The anorectal angle is accepted as the anatomical anorectal junction. The *internal sphincter* is a condensation of the circular muscle of the bowel wall. When the external sphincter is relaxed, the distal edge of the internal sphincter can generally be felt at the anal verge (Figure 15.2). However, as the subcutaneous fibres of the external sphincter contract, they form a circle of muscle distal to, rather than around, the internal sphincter. The *external sphincter* is a composite striated muscle. Its lower fibres encircle the anal canal and can be, somewhat arbitrarily, subdivided into deep, superficial and subcutaneous portions. Superiorly, the external sphincter blends with the puborectalis portion of the levator ani muscle. The circular portion of the external sphincter is shorter in women, particularly anteriorly. The puborectalis sling and the sphincter muscles together maintain anal continence.

The lining of the anal canal changes at the *dentate line*. Below this line is modified skin, or anoderm, consisting of squamous epithelium, but above the line the mucosa is a similar columnar epithelium to that of the remainder of the colon and rectum, except that there is a *junctional zone* extending for about 1 cm above the dentate line. This change in the mucosa is important, as malignant lesions arising in the distal anal canal are more likely to be squamous cell carcinomas than adenocarcinomas. The dentate line also marks the watershed for lymphatic drainage. The upper anal canal drains predominantly to the inferior mesenteric nodes and the lower anal canal drains to the superficial inguinal nodes. The dentate line is also the division between somatic and visceral sensation. Distal anal canal pathology may be extremely painful, whereas pain is a later feature of pathology at, and above, the anorectal junction. This is also the reason it is possible for a surgeon to inject sclerosants or place mucosal rubber bands *above* the dentate line with only minor discomfort. The dentate line can be identified visually, as the mucosa above is loosely attached and hangs in longitudinal folds, which are joined at the dentate line by crescentic folds, or *anal valves* (see Figure 15.2). The *anal glands* lie partly in the submucosal plane and partly between the sphincters in

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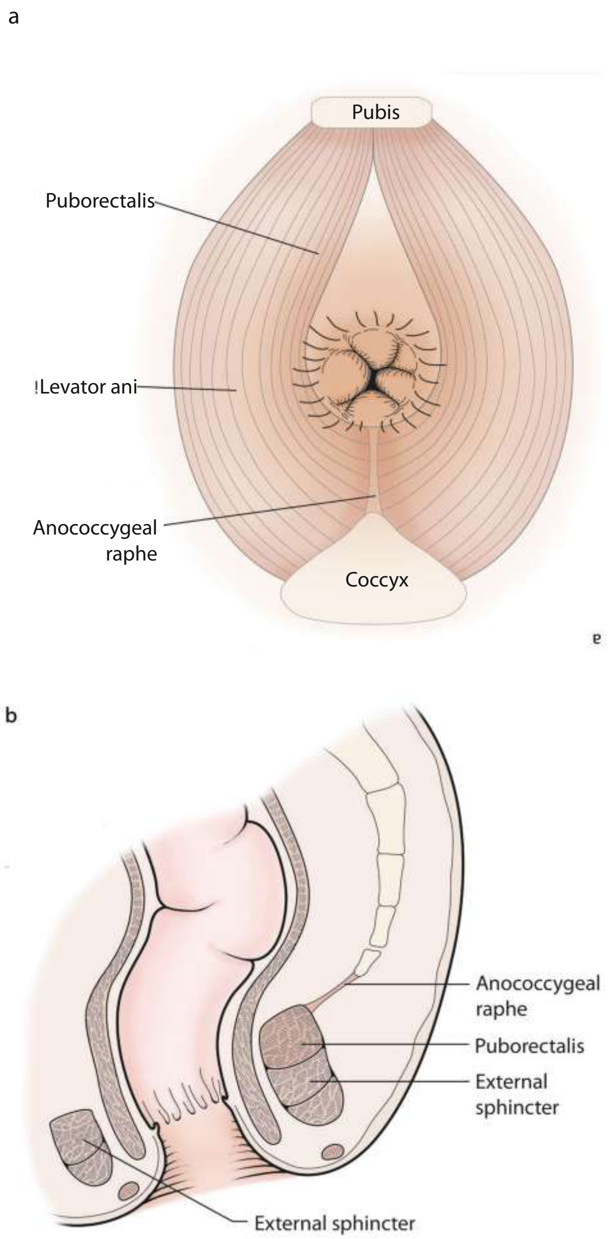
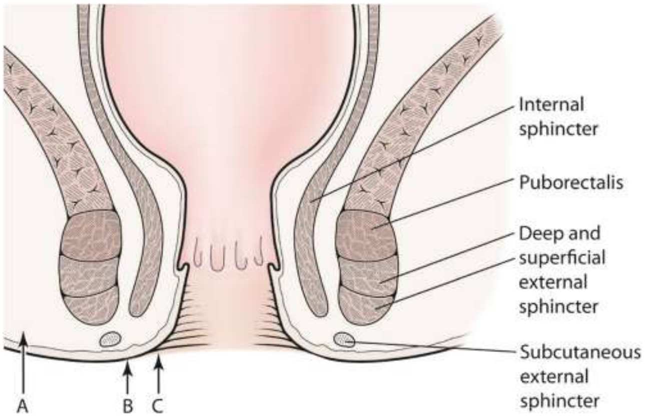


15.1 Diagrammatic representation of the puborectalis muscle. (a) The pelvic floor musculature viewed from below. The puborectalis sling is the anteromedial free edge of the levator ani muscle and is of great importance in continence, although it does not encircle the anus. (b) The diagrammatic sagittal view of the anus demonstrates the absence of puborectalis anteriorly. ⏎

the intersphincteric plane; infection in these glands is thought to be the main cause of perianal sepsis and fistulae. The orifices of the glands open just above the anal valves and this is therefore the most common site of the internal opening for a fistula (see the section 'Anal fistulae').

Vascular plexuses lie beneath the mucosa of the anal canal. The main arterial inflow is from the terminal branches of the superior rectal artery, which classically divides into a left lateral, a right anterolateral and a right posterolateral branch. These branches anastomose with branches of the inferior rectal artery. Three small swellings, or *anal cushions*, are associated with the underlying vascular plexuses. A *haemorrhoid* is an excessive distension of a vascular plexus, which stretches the overlying mucosa and anoderm, loosening their attachments to the muscle wall of the anal canal.


Internal sphincter
Puborectalis
Deep and superficial external sphincter
Subcutaneous external sphincter
A
B
C

15.2 Diagrammatic coronal section of the anal canal. The longitudinal anal folds terminate in the anal valves at the dentate line. The extrasphincteric plane (A) is the fat of the ischiorectal fossa beneath the levator ani muscles. In the relaxed anus, the subcutaneous fibres of the external sphincter lie outside the internal sphincter, and the intersphincteric groove (B) is palpable. The submucosal plane (C) is continuous with the subcutaneous plane beneath the anoderm. ⏎

PHYSIOLOGY

Defecation

Defecation takes place as a result of coordinated relaxation of the anal sphincter muscles and pelvic floor along with a propulsive peristaltic wave. Voluntary straining to increase intra-abdominal pressure is usually an additional feature. Straining will overcome difficulties in evacuation secondary to poor sphincter or pelvic floor relaxation, to inadequate peristaltic wave or to a disproportionally large stool. However, straining also causes haemorrhoidal swelling and symptoms such as bleeding and prolapse of haemorrhoidal tissue. Moreover, some patients develop more severe difficulties and present with a range of symptoms, collectively described as 'obstructed defecation syndrome'. These patients complain of incapacitating evacuatory problems often associated with tenesmus. The difficulty is thought to be, at least in part, due to failure of relaxation or even inappropriate contraction of the pelvic floor during defecation. Trauma from straining can cause an ulcer, which is commonly in the low rectum anteriorly (solitary rectal ulcer). Intrarectal intussusception and even full-thickness rectal prolapse may also develop. Excessive perineal descent from straining can also stretch and damage the pudendal nerves. It is important to recognise that the anatomical abnormalities that are found on clinical examination and radiological evaluation are the consequences of obstructed defecation and not the cause. Surgery seldom has any place in the treatment of obstructed defecation, and biofeedback has proved to be the most promising line of management.

After rectal resection, and the formation of a coloanal or ileal pouch–anal anastomosis, there is inevitably a deficient afferent limb to any defecatory reflex initiated by the presence of faeces above the sphincter. There was an initial theoretical concern that evacuatory function would be seriously impaired, but this has not proved to be a major problem.

Continence

Continence is also complex, as it is a balance between the effectiveness of the anal sphincters, in conjunction with the levator ani, and the pressures that they must withstand. Severe dysentery can cause incontinence, even in young men with excellent sphincters. Conversely, some older women with little measurable sphincter function may remain 'continent' due to a regular and somewhat constipated bowel habit, only to complain of incontinence when they develop some other large bowel pathology. Sphincter pressures naturally decline with age as muscle fibres in the sphincters are replaced with fibrous tissue. This natural deterioration also affects the muscles of the pelvic floor. The ability to detect flatus or faeces in the lower rectum or anal canal, and to differentiate between them, is another factor in the maintenance of continence. Deterioration in anorectal sensation also occurs with advancing age. However, partial sphincter denervation from pudendal nerve neuropathy is less important than was previously believed.

Resting anal pressure Passive continence is the ability to prevent passive leakage of rectal contents. Leakage can occur without a major propulsive peristaltic wave and is prevented by an effective anal seal and the resting anal pressure. The haemorrhoidal cushions form a soft seal to the anal canal, but the seal is mainly dependent on the activity of the unstriated muscle of the internal sphincter. Of equal importance is whether the lower rectum has faecal matter within it and the consistency of that matter. Good passive continence is imperative in preventing leakage of semi-formed stool, as is the case with ileal pouch contents and, therefore, because anal pressures decrease with advancing years, a pouch–anal reconstruction may not be a good solution for an older patient. Blood and mucus in the lower rectum present a similar challenge to continence, and an older patient with a rectal cancer, or villous adenoma, may present with passive incontinence. A patient with a very poor resting anal pressure who suffers from incomplete evacuation on defecation may lose small pellets of solid faeces. This problem will be compounded if anorectal sensation is poor and the patient is unaware of the passage of stool.

Anal squeeze pressure This is the maximum voluntary pressure that the patient can exert to close the anal canal and is thus of more importance in delaying a call to stool than in maintaining passive continence. The voluntary increase in pressure is produced mainly by the external sphincter, but is supplemented by other muscles of the pelvic floor and even by gluteal muscle contraction. These additional muscles of continence may be sufficient to compensate for a severely disrupted external sphincter after childbirth. A young woman may initially maintain acceptable continence but present with impaired continence years later as other compensatory muscles atrophy with advancing age. The ability to delay defecation is not solely related to sphincter integrity. The strength of the peristaltic waves in infective colitis, diverticular disease or inflammatory bowel disease may challenge continence in patients with a normal sphincter. An additional factor is the volume and compliance of the rectum, or neorectum, to accommodate and store additional faecal material.

Anorectal physiology, including investigation of the physiology, and the maintenance of continence are complex subjects and further reading on these topics is recommended.[1]

GENERAL TECHNIQUE

SURGICAL APPROACH

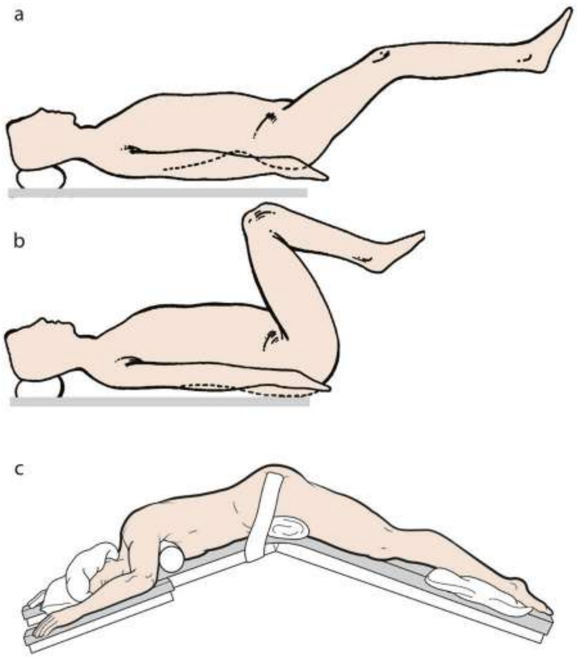
The importance of anal operations is often underestimated, and the surgery is commonly delegated to relatively inexperienced surgeons. However, unless this surgery is undertaken to a high standard and with attention to detail, there is considerable potential for avoidable iatrogenic damage.

Anaesthesia

Adequate anaesthesia – whether general, regional or local infiltrative – is essential for any procedure on the sensitive anoderm below the dentate line. For peranal surgery on the relatively insensitive rectum, the role of anaesthesia is predominately to relax the anal sphincters in order to facilitate access.

Access

Surgery on the anal canal is usually performed with the patient positioned in the lithotomy or jack-knife positions (Figure 15.3). The lithotomy position is most commonly used, as it provides excellent access. The prone jack-knife position is more ergonomically suited to access the posterior perineum and the anterior wall of the anal canal for transluminal procedures. Visualisation is difficult in the presence of faeces in the rectum. A preoperative enema is usually sufficient to clear the operative field. A proctoscope holds the anus open and allows visualisation of, and access to, the lower rectum. A Sims retractor is used for unilateral anal retraction and displays the opposite half of the anal canal. However, bivalve retractors, a variety of which are available, usually afford superior access with visualisation of, and surgical access to, the anus between the blades of the retractor. The Lone Star System™ gives excellent self-retaining retraction, with a series of disposable skin hooks that are inserted circumferentially. Each small hook is at the end of a long, slim plastic-covered spring, which is then fixed onto the circumference of the ring retractor encircling the anus. However, prolonged or excessive anal retraction by any method can damage the internal sphincter and great care must be exercised to minimise the extent and duration of the retraction. A head-mounted light is useful in providing a well-illuminated operating field.



15.3 Positioning for procedures on the anal canal. (a) The Lloyd-Davies position is suitable for a lengthy procedure in which abdominal and perineal access is required. Perineal access is restricted even when a steep head-down tilt is employed. (b) The lithotomy position is a better position for any anal dissection, but the acute flexion of hips and knees is undesirable for any protracted period. The position of the thighs also restricts any simultaneous pelvic or abdominal access. (c) The prone jack-knife position with the buttocks strapped apart affords excellent access to the posterior perineum and anus with less venous congestion. The disadvantages are mainly in the turning and ventilation of an anaesthetised patient in this position, which makes it an unattractive option for a short, minor procedure. ⏎

Preparation

Anal operations should commence with a digital rectal examination and proctoscopy. If any external wound has been planned, the perianal skin should be shaved at the start of the procedure, as hair matted with blood will become adherent postoperatively and greatly increase patient discomfort.

Dissection

Precise dissection in anatomical planes and the identification of the sphincters is the key to successful anal surgery (see Figure 15.2). Uncontrolled haemorrhage during dissection obscures vision and must be avoided. Therefore, diathermy dissection has considerable advantages. External sphincter fibres twitch when stimulated by diathermy current, and this observation can aid identification during dissection. Injection of a dilute solution of adrenaline (1:400,000) before commencing surgery will reduce haemorrhage and, if injected into the proposed dissection plane, can make the dissection easier. While some surgeons favour this technique, others claim that injection distorts the anatomy and is unhelpful. The editors favour dilute adrenaline injection. Three different anatomical planes may be followed in anal surgery:

1. The *submucosal plane* for a haemorrhoidectomy is entered outside the anal verge; for a mucosectomy, the plane is entered at the dentate line and, for a Delorme's procedure, the plane is entered 1–2 cm above the dentate line. In a transanal excision of a villous adenoma, the submucosal plane is entered close to the base of the tumour.
2. The *intersphincteric plane* is the key to anal sepsis and fistulae. It is also the plane through which the rectum can be excised either from above or from below (the latter for benign conditions). It is entered from below at the palpable intersphincteric groove at the anal verge.
3. The *extrasphincteric plane*, which is entered when draining an ischiorectal abscess, ends blindly at the pelvic floor musculature. This is also the plane for abdominoperineal excision of the rectum (see Chapter 14). A rectocoele can be approached

through the extrasphincteric plane, between the circumferential portion of the external sphincter and the vaginal mucosa, as there is an anatomical window through the pelvic floor in the midline anteriorly (see Figure 15.1). To enter the extrasphincteric plane from the perineum, the surgeon must be confident of the position of the external sphincter. The perianal skin is more deeply pigmented for a few centimetres outside the anal verge, and the change to normal pigmentation is the surface landmark of the external sphincter.

The anal wound

Any bleeding from a raw surface should be stopped by diathermy coagulation. The traditional large anal pack is almost always unnecessary and causes significant postoperative pain. A small absorbable haemostatic pack is favoured by some surgeons, but is expensive. Local infiltration of bupivacaine with adrenaline is effective in arresting minor ooze and will also reduce early postoperative pain. Perianal skin wounds are often left open, and a greased dressing will prevent adherence to clothes or pads and reduce discomfort. Absorbable sutures may be used on the anal mucosa and the anal verge skin.

Faecal contamination of an anal wound seldom gives rise to major local or systemic sepsis.[2] It is even safe to use non-absorbable material for suturing the anal sphincters, although the use of non-absorbable mesh should generally be avoided. However, minor infection is common and is believed to be the cause of the increase in postoperative pain at about 3–5 days after a haemorrhoidectomy.[3] The early passage of hard faeces causes pain and even mechanical disruption of a repair. Postoperatively, stool softeners are used routinely to encourage an early soft motion. The addition of a course of preoperative stool softeners will be more effective in achieving this. A temporary defunctioning stoma should be considered in some circumstances.

POSTOPERATIVE COMPLICATIONS

- *Urinary retention* due to pain is common after anal procedures and in complex perineal operations anterior to the anus. Therefore, prophylactic urethral catheterisation should be considered selectively, particularly in men.
- *Early haemorrhage* after anal surgery is usually best treated by a return to the operating theatre, examination under anaesthesia and coagulation or ligation of the bleeding point.
- *Secondary haemorrhage* at 10–14 days may be profuse. As neither sutures nor diathermy are likely to arrest the bleeding from friable infected granulation tissue, it is initially treated conservatively with blood replacement and antibiotics. If bleeding continues, it is best to examine the patient under anaesthesia and try to achieve haemostasis. If haemorrhage is diffuse from granulation tissue, tamponade using a pack, or a balloon catheter, is usually effective in controlling diffuse haemorrhage.
- *Anal stenosis* and *anal mucosal ectropion* are late complications of anal surgery when too much anoderm has been removed. Stenosis and anal mucosal ectropion occur mainly after haemorrhoidal surgery. For many mild forms, conservative management with anal dilators, stool softeners and protection of the perianal skin from minor discharge often suffices. More severe symptoms may require surgery. A simple Y–V advancement flap may help (see Figures 15.7a and 15.8).

HAEMORRHOIDS

Haemorrhoids are a distension of the normal vascular haemorrhoidal cushions. *Internal haemorrhoids* are submucosal and above the dentate line. Initially, symptoms are confined to bleeding, during or after defecation (first degree). As the distension progressively increases, the lax mucosa gets separated from the underlying muscle wall by the distended vascular plexus and prolapses along with the haemorrhoidal tissue during defecation, which initially reduces spontaneously after defecation (second degree). Haemorrhoids that no longer reduce spontaneously (third degree) require digital replacement. Failure of replacement may progress to *thrombosed prolapsed internal haemorrhoids*, which are also described as *strangulated piles*, although the strangulating effect of the sphincters is variable.

There is frequently some extension of haemorrhoidal tissue below the dentate line, and the distension of this tissue, combined with prolapsing from above, separates the entire anal canal epithelium from the underlying muscle wall. The anus becomes protuberant, with the external component of the haemorrhoids visible as broad-based tags at the anal verge. These are predominantly skin covered, although there may be mucosa visible on eversion of the tag. Permanently prolapsed haemorrhoids (fourth degree) produce a mucous discharge as a result of mucosal irritation due to exposure.

External haemorrhoids are vascular plexuses beneath the perianal skin and are often unrelated to internal haemorrhoids. Bleeding from an external haemorrhoid can produce a perianal haematoma, which is extremely painful but usually starts to resolve spontaneously within a few days, often with the formation of a perianal skin tag.

Patients with mild symptoms of haemorrhoids require no intervention other than exclusion of a rectal neoplasm or other serious pathology. Treatment, to be effective, must either reduce the size and vascularity of the haemorrhoidal cushions or reduce the laxity between the anal canal epithelium and the muscle to prevent the mucosal prolapse. These objectives can often be achieved by outpatient treatment, without surgery.

TREATMENT OF HAEMORRHOIDS

The mainstay of treatment for haemorrhoids is to avoid excessive straining and improve stool consistency. This can usually be achieved by lifestyle modifications in the form of increased intake of insoluble fibre and adequate oral hydration.

A large number of proprietary topical treatments exist. These usually contain a mixture of steroid and barrier cream. They provide symptomatic relief for an inflamed haemorrhoid or for perianal skin damaged by faecal seepage, but will not result in resolution of the underlying haemorrhoids, and more definitive treatment may be required.

Outpatient treatment of haemorrhoids

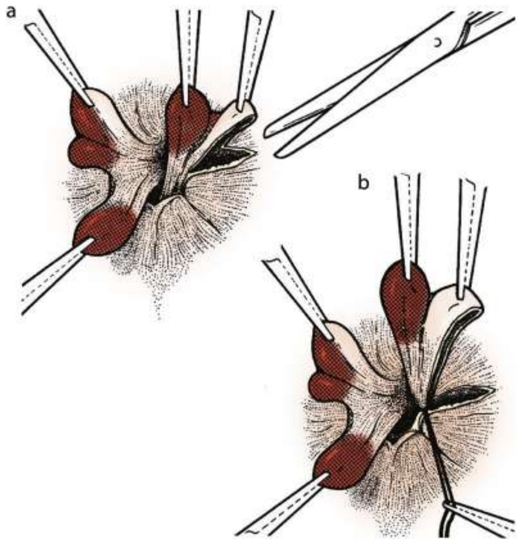
Small haemorrhoids can be treated by occluding the feeding vessel to prevent the inflow of blood. These treatments are usually effective for first-degree and small second-degree haemorrhoids. Larger haemorrhoids may require several treatments at 6-week intervals and may not resolve with non-operative treatments. The feeding vessels enter the haemorrhoid proximally, well above the dentate line, in the insensate rectal mucosa. Provided treatment is at this level, little pain results and the procedure can be carried out through a proctoscope in the awake patient. Several options exist for occluding the feeding vessel.

Sclerotherapy A submucosal injection of sodium tetradecyl sulphate or ALTA causes both thrombosis of the feeding vessels and fibrosis of the haemorrhoidal cushion, which tethers the lax mucosa, thus reducing prolapse. Injection of 2–3 mL immediately above each haemorrhoid should be seen to raise a pale swelling, which spreads in the submucosal plane. A white wheal indicates too superficial an injection into the mucosa. Too deep an injection anteriorly may have serious consequences. Chemical prostatitis and impotence are rare but well-recognised complications in men, and anovaginal fistulae have been reported in women. Minor septic reactions are not uncommon and occasionally, as with any interventional treatment, severe sepsis can occur.[2]

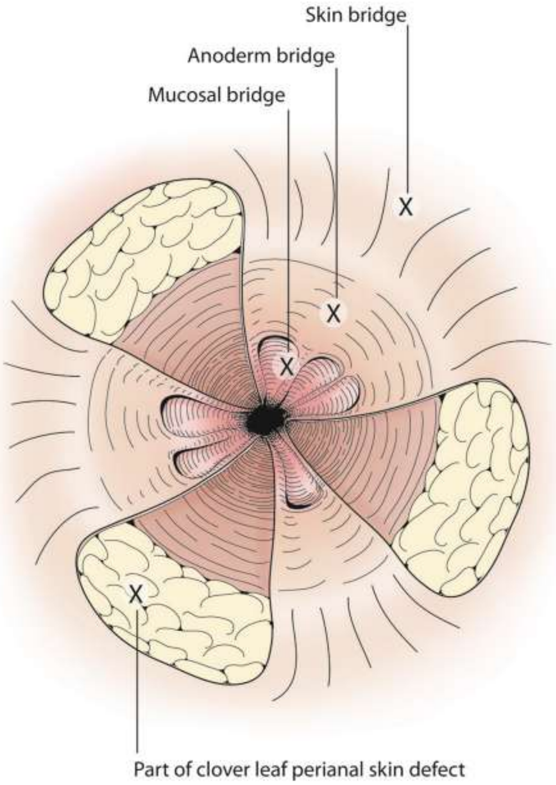
Banding To band a haemorrhoid, the mucosa immediately above the haemorrhoid is drawn into a suction device, which then deploys a rubber band over the mucosa. The contained mucosa and vascular plexus are strangulated, and separate, at around 10–12 days. Banding is more effective for prolapsing (second- and third-degree) haemorrhoids than sclerotherapy, but, even if the band is safely above the dentate line, the occasional patient experiences severe pain a few hours later and, in general, discomfort is more common with banding. A secondary haemorrhage, which is occasionally profuse, may occur as the strangulated tissue separates.

Surgical treatment of haemorrhoids

Milligan–Morgan (open) haemorrhoidectomy[4] In this classical operation, haemorrhoidal tissue is excised radially at one or more sites, and each excision includes the external skin component of the haemorrhoidal complex in continuity with a strip of anal canal mucosa and the underlying haemorrhoidal plexus (Figure 15.4). Adequate bridges of skin and mucosa must be left intact between the excisions to prevent the development of anal stenosis. This is particularly important in the anal canal below the dentate line and at the anal verge (Figure 15.5). The dissection is in a



15.4 The classic Milligan–Morgan haemorrhoidectomy. (a) Artery forceps have been applied to the skin and to the mucosal elements of each haemorrhoid. A V-shaped incision is made beneath the external skin element of the haemorrhoid and the haemorrhoid is dissected off the underlying internal sphincter.
(b) The mucosal and submucosal pedicle at the proximal extremity of the haemorrhoid is transfixed and ligated. ⏎



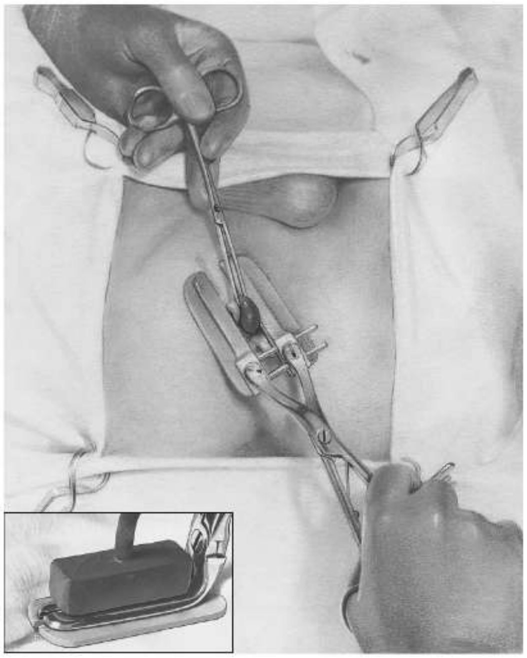
15.5 A clover leaf-shaped defect in the anal canal and perianal skin will be left after a haemorrhoidectomy. It is important that intact bridges of mucosa, anoderm and perianal skin are retained. ⏎

submucosal plane deep to the haemorrhoidal plexus and superficial to the internal sphincter muscle, which must be identified and preserved. An anal retractor can make identification of the internal sphincter easier, but care must be taken not to overstretch the anus. A retractor will also help to keep the other haemorrhoids out of the operative field and is rotated to display each haemorrhoid in turn.

The *operative procedure* is as follows. A pair of artery forceps is applied to the skin element of each haemorrhoid and a second pair of forceps is applied to its prolapsing mucosa. These artery forceps hold the haemorrhoid for dissection, but they can also be used to retract the other haemorrhoids out of the operative field if an anal retractor is not employed. It is often easier to mark all the incisions in the anal canal, to ensure adequate skin and mucosal bridges between the excisions, before proceeding with the removal of the first haemorrhoid. A fine diathermy point is ideal, as it incises the anoderm and mucosa with minimal bleeding. Excision of the first haemorrhoid is then commenced with a V-shaped incision through the skin at the base of the external component (see Figure 15.4a). The V-shaped incision is extended across the anal verge to join the preliminary superficial marking incisions and defines the tissue to be excised. The dissection is deepened under the V to develop the plane outside the haemorrhoidal tissue, but great care must be exercised to ensure that this dissection is *inside* the internal sphincter. The muscle fibres should be clearly visualised and preserved. The haemorrhoidal tissue is dissected off the underlying internal sphincter, up into the anal canal, until the haemorrhoid is attached only by its pedicle of mucosa and the feeding vessels of the plexus. This pedicle is either secured by a transfixion suture or simply divided by diathermy and the haemorrhoid removed (see Figure 15.4b). The surgeon is often concerned by the residual haemorrhoidal tissue left *in situ* under the bridges of stretched, and prolapsed, mucosa and anoderm. In almost every patient, healing with scar contraction draws this tissue back into the anal canal and reattaches it to the muscle coat. Modifications include:

- In *Ferguson (closed) haemorrhoidectomy*, on completion of the operation, the mucosa and skin can be closed with absorbable sutures. Haemostasis must be meticulous or an infected haematoma will form deep to the closure and disrupt the wound.
- *Park's submucosal excision* differs in that a linear radial incision is made over the haemorrhoidal tissue, which is then dissected out from beneath the anoderm and mucosa. No epithelium is excised and the wound is closed.
- *Radial clamps or staples* can be used to remove the lax, stretched, anal mucosa and anoderm with the underlying haemorrhoidal plexus.[5] Both the linear stapler and the LigaSure™ techniques follow similar principles to the traditional clamp and cautery favoured by Eric Farquharson (Figure 15.6). In these techniques, the internal sphincter is at a higher risk of damage.

Circular stapling or anopexy This method has the disadvantage of the high cost of a disposable stapling device. It is normally performed under general anaesthesia, but postoperative pain is usually minimal, as there is no wound below the dentate line. A circumferential mucosal purse-string suture is first placed *per anum* 3–5 cm above the dentate line, so that tightening of this purse-string will draw mucosa and submucosa into the stapler. When the stapler is closed and fired, a ring of staples is delivered and a 'doughnut' of mucosa and submucosa is excised, which includes the arterial inflow to the upper end of the haemorrhoids. Vascularity is reduced and prolapsing haemorrhoidal mucosa is drawn back up into the anal canal. Too low a purse-string results in severe pain, while a purse-string that is too deep and incorporates muscle results



15.6 A photograph from the original 1954 edition of a clamp and cautery haemorrhoidectomy in Eric Farquharson's unit. ⏎

in a full-thickness circular excision with the potential to cause pelvic sepsis or a rectovaginal fistula. More widespread use is limited by cost and is also related to concerns over complications.

Haemorrhoidal artery ligation In a haemorrhoidal artery ligation operation (HALO), the arteries feeding the haemorrhoidal plexus are ligated to reduce the inflow. Postoperative pain is again usually minimal. A special proctoscope containing a Doppler ultrasound probe is used to identify the site of the haemorrhoidal arteries. The probe is then removed and a figure-of-eight suture placed deeply through the rectal mucosa at the site of the identified vessel, several centimetres above the dentate line. The suture is tied, using a knot pusher, to occlude the feeding vessel. The same suture can then be used to plicate the haemorrhoidal tissue by taking a series of bites down to just proximal to the dentate line. When the suture is again tied, any prolapsing component of the haemorrhoid is drawn back above the sphincters. The proctoscope is then turned, and the procedure repeated at further sites where arterial blood flow is detected by the ultrasound probe. Often, six or seven vessels are detected and all should be ligated.

Ablative procedures Laser and radiofrequency ablation are slowly gaining popularity due to reports of less postoperative pain and quick return to daily activities. Thermal destruction of tissues leads to obliteration of vascular channels, fibrosis and shrinkage. Care must be taken to understand the anatomy prior to undertaking such procedures, to avoid thermal injury to the underlying sphincter complex.

Thrombosed (strangulated) prolapsed internal haemorrhoids

Patients with prolapsed, thrombosed, mucosa-covered haemorrhoids are often in severe pain. Traditionally, surgery was postponed because of concern that intervention in the acute situation was associated with an increased risk of sepsis. Conservative treatment was aimed at pain relief. An anal stretch was effective, but only because it abolished anal spasm by partial disruption of the sphincters. Local applications of hyaluronidase or ice were also used, in addition to sugar or salt, to reduce swelling by osmosis. It is now considered more appropriate to simply proceed with a haemorrhoidectomy. However, great care must be exercised, as the anatomical distortion may increase the risk of both sphincter damage and anal stenosis. It is usually advised that it is better to excise the largest, or at most two, haemorrhoidal area(s) rather than attempt a full haemorrhoidectomy.

Perianal haematoma (thrombosed external haemorrhoids)

Evacuation of the haematoma, as for the drainage of a perianal abscess, may shorten the natural history, but conservative management is usually equally satisfactory.

Anal tags

Anal tags may cause irritation and difficulties with hygiene, and a patient may request excision. The removal of small tags can be disappointing, as a new tag sometimes forms on healing. Narrow-stalked tags can be simply excised under local anaesthesia, but careful preoperative assessment is important. The tag may be a sentinel pile marking an underlying anal fissure or it may be the broad-based external component of an associated internal haemorrhoid. Treatment should then be of the underlying pathology, which is more likely to be the cause of the symptoms than the tag itself.

ANAL FISSURES

Simple anal fissures occur almost exclusively in the midline, both anteriorly and posteriorly. The acute anal fissure is a radial split in the anoderm extending from the anal verge for a variable distance proximally towards the dentate line. These fissures are seen in association with constipation, childbirth and severe diarrhoea. Straining with failure of relaxation of the internal sphincter may also be implicated as a causative or contributory factor. Chronic anal fissures are those that fail to heal and form a linear, indurated chronic ulcer. Patients request treatment for defecatory bleeding and severe post-defecatory pain. There is considerable evidence that failure to heal is, at least in part, due to localised tissue ischaemia from high anal pressure. A permanent surgical or temporary pharmacological reduction in the resting anal pressure is the mainstay of treatment.

Fissures associated with Crohn's disease are often multiple, atypical and not in the midline and may extend proximal to the dentate line. In general, surgery should be avoided. The surgeon must also be aware of other chronic ulcers in the anus including anal carcinoma and ulcers secondary to infection with cytomegalovirus (CMV) or syphilis.[1] If the aetiology is in doubt, and especially if squamous cell carcinoma is a possibility, the patient should be examined under anaesthesia, the fissure assessed, a swab taken for bacteriological investigations and a biopsy sent for histology.

TREATMENT OF ANAL FISSURES

As with haemorrhoids, lifestyle modification is crucial for healing and preventing recurrence. A sitz bath in warm water relaxes the anal sphincter and improves blood flow, promoting healing. Additives to the sitz bath are not recommended. The treatment for anal fissures depends on the tone of the sphincters.

Hypertonic anal sphincters

Topical treatments are effective for most simple anal fissures. Diltiazem (2%) and nifedipine (0.3%) are the most widely used agents along with lignocaine (2%). Although some early relief may be achieved from reducing painful sphincter spasm, treatment should be continued for 6–8 weeks to allow time for the fissure to heal.

Botulinum toxin injection Botulinum toxin injection into the internal sphincter decreases the anal sphincter tone by inhibiting the release of acetylcholine. Injection of up to 50 units bilaterally can be done as an outpatient procedure, to relax the sphincters, giving the fissure time to heal. Incontinence, if any, is temporary and therefore the procedure can be repeated as needed.[6]

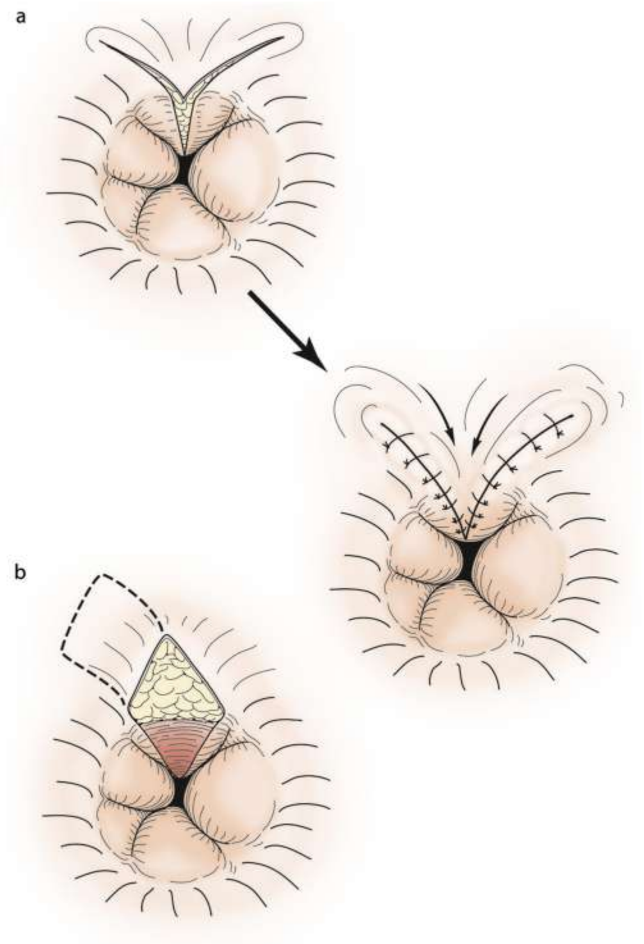
Subcutaneous lateral internal sphincterotomy A partial internal anal sphincter release is very effective in reducing resting tone, relieving the symptoms and healing the fissure. Many patients, however, will have a minor deterioration in continence and a few will have significant problems.[7] There has been increasing awareness of the fact that women with childbirth-related sphincter damage often compensate for many years and present in later life with incontinence, which has also raised surgical awareness of late morbidity from partial division of the sphincters. Sphincterotomy has therefore largely fallen out of favour, except when more conservative measures have failed and a patient is willing to accept the risk of impaired continence.

Subcutaneous lateral internal sphincterotomy (SLIS) consists of partial division of the internal sphincter. The length of the fissure may be a good guide to the length of the release indicated. Inadequate release results in treatment failure and too generous a release increases the likelihood of passive incontinence.

The *operative procedure* is as follows. With the patient anaesthetised, the intersphincteric groove is palpable at the anal verge (see Figure 15.2). In the *open method*, a 1–2 cm circumferential incision is made at the anal verge over the free edge of the internal sphincter, usually at the 3 o'clock position. Blunt scissor dissection opens the plane inside and outside the internal sphincter to free it. The free lower edge of the internal sphincter is then grasped and drawn into the wound and its distal portion divided. In the *closed method*, a pointed No 11 blade is introduced between the internal sphincter and the anoderm, with the blade orientated so that it lies parallel to the anal skin. It is then rotated to face outwards and gently pressed against the distal portion of the internal sphincter, which is held taut with a bivalve retractor. The scalpel is withdrawn and on digital palpation the tight band of the distal internal sphincter can be felt to have been released. Any residual band will 'give way' on gentle digital pressure on the anoderm over the area of the release. This is safer than reintroducing the scalpel. There is often an associated sentinel skin tag at the outer end of the fissure and sometimes a fibroepithelial polyp at the inner end. These should be excised. The wounds are left open.

Normotonic or hypotonic sphincters

Advancement flaps A chronic fissure, which has not healed on conservative management, may also be unsuitable for any form of sphincterotomy. For example, the patient may already have some impairment of continence or is known to have had external sphincter damage during a forceps delivery. Some fissures also occur in the presence of a low resting anal pressure, and sphincterotomy is not expected to heal these. Excision of the fissure and sentinel pile with preservation of the integrity of the internal sphincter can be followed by a diamond-shaped anal advancement

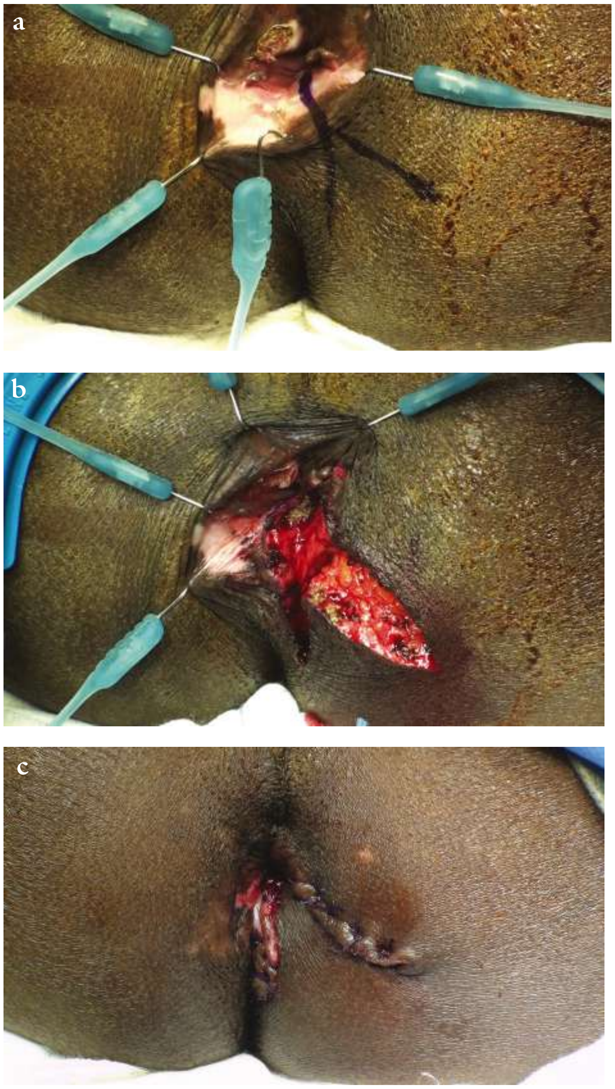


15.7 Local perianal flaps. (a) A Y–V anal advancement flap is a simple procedure for an anal stenosis. The Y incision at the anterior anal verge has been closed as a V, bringing extra tissue into the stenosed anus. (b) A chronic anal fissure can be excised and a local flap of healthy perianal skin and subcutaneous tissue brought in to fill the defect. The excision of this posterior fissure has left a diamond-shaped defect. The flap has been marked. It will be left attached to the underlying tissue from which it obtains its blood supply. The resultant donor defect can be closed or left to granulate. ⏎

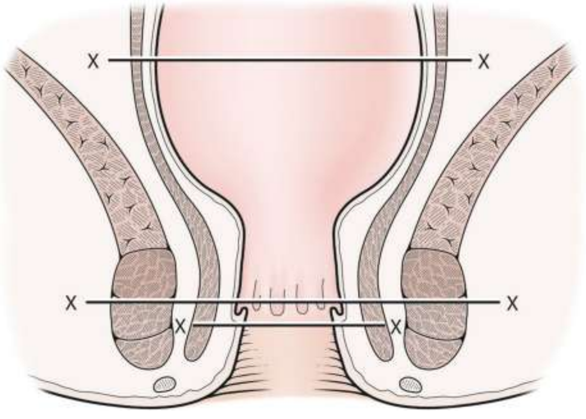
flap to bring healthy, well-vascularised tissue into the fissure bed (Figure 15.7b).

ANAL SEPSIS

Anal and perianal sepsis are commonly confined to a compartment defined by muscle and fascial attachments (see Figure 15.2). These compartments are all circumferential and pus may therefore track around the anus in any plane (Figure 15.9). The circumferential tracking of pus is more frequent posteriorly and has implications in the treatment of fistulae.



15.8 A Y–V advancement flap for anal stenosis. (a) A Y-shaped incision is marked at the anal verge. (b) Flaps are raised, consisting of skin and subcutaneous tissue, preserving the sphincter muscles. (c) The incision is closed as a V, bringing tissue into the stenosed anus. ⏎



15.9 Pus can track circumferentially in any perianal plane. ⏎

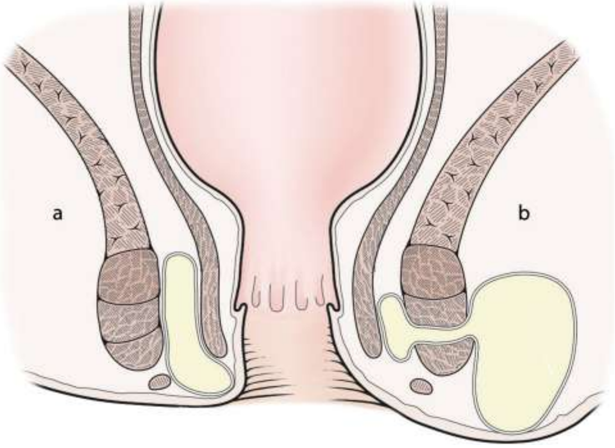
INTERSPHINCTERIC ABSCESS AND ITS SEQUELAE

Intersphincteric abscess

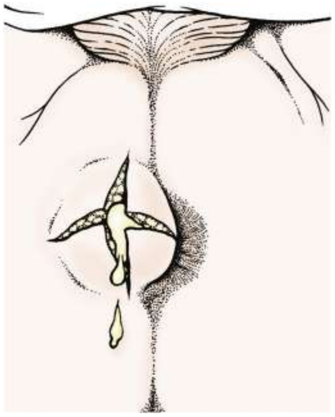
Most perianal sepsis starts in the intersphincteric space, in association with infection within an anal gland. Occasionally, an intersphincteric infection will fail to 'point' and present with severe anal pain without an obvious explanation. A magnetic resonance imaging (MRI) scan of the pelvis or, alternatively, an endoanal ultrasound under anaesthesia will elucidate the underlying pathology. On other occasions, the pus discharges spontaneously into the anal canal. If the patient is first seen at this stage, the atypical ragged ulceration can mimic more serious pathology. More frequently, the pus tracks down to the anal verge to present as a perianal abscess or tracks through the external sphincter to form an ischiorectal abscess. Pus in all of these abscesses has a potential, or an established track, to the lumen of the anal canal along the duct of the anal gland in which the infection originated.

Perianal abscess

A perianal abscess presents as a painful superficial swelling that distorts the anal verge (Figure 15.10). There may be a considerable collection of pus extending both cranially and caudally in the intersphincteric plane and pus may even track up into the supralevator space (see Figure 15.12). Drainage is achieved with a cruciate incision over the swelling at the anal verge. The cavity is then deroofed, either with an elliptical incision or by the excision of the four flaps created by the initial cruciate incision, to allow good drainage (Figure 15.11). Any associated intersphincteric anal fistula should not be explored in the acute phase.



15.10 Pus in the intersphincteric plane may track down to point as a perianal abscess (a), which distorts the anal verge. Alternatively, it may track through the external sphincter to form an ischiorectal abscess (b), which is deeper and points late to an area a few centimetres lateral to the anal verge. ⏎



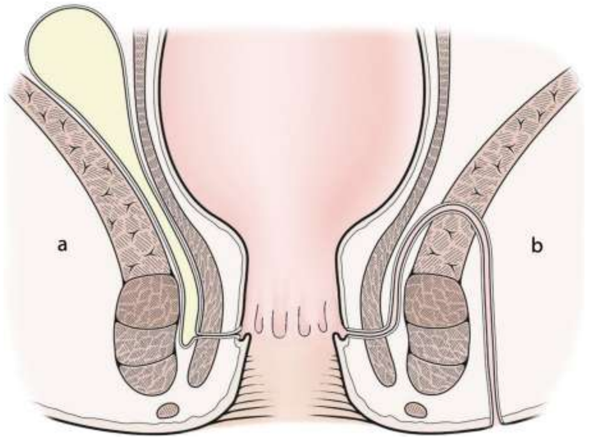
15.11 A perianal abscess drained by a cruciate incision at the anal verge. ⏎

Ischiorectal abscess

An ischiorectal abscess presents with evidence of deep pus in the fat of the ischiorectal fossa, and the swelling is a few centimetres away from the anus (see Figure 15.10b). In the early stages, fluctuation and erythema of the overlying skin may be absent. Treatment again consists of drainage and deroofing of this deep abscess. The incision must be sufficiently large to allow continued drainage of any residual pus and to prevent premature closure of the skin. A drain into the depths of the abscess is usually superfluous and increases discomfort. A temporary pack can be useful as a means of achieving postoperative haemostasis. Repeat packing is not recommended, as it merely delays healing. The majority of ischiorectal abscesses are associated with an underlying trans-sphincteric fistula, following intersphincteric sepsis that has burst through the external sphincter. However, the fistula should not be explored until the acute inflammation has settled.

Supralevator abscess

Pus may extend cranially in the intersphincteric plane into the supralevator compartment (Figure 15.12a). However, pus can also track to this compartment from an ischiorectal abscess with a blind cranial extension penetrating the levator ani muscle. In addition, supralevator pus can be secondary to deep pelvic sepsis, and this pus may even track spontaneously through the levators distally into the ischiorectal fossa. Pus above the levator ani muscles must therefore be carefully assessed, as inappropriate drainage from below can create a suprasphincteric or an extrasphincteric fistula. In Figure 15.12b, supralevator pus



15.12 Intersphincteric sepsis can track up into the supralevator compartment (a) and drainage of such an abscess through the levators will result in a suprasphincteric fistula (b). This is a high fistula, despite an internal opening at the dentate line. ⏎

from a large intersphincteric abscess has been drained through the levator ani, with a resultant suprasphincteric fistula. When the primary pathology is located in the pelvis, associated with a paracolic abscess, an iatrogenic extrasphincteric fistula may result unless the sepsis is drained from the abdomen. It is best to assess these patients with cross-sectional imaging (computed tomography [CT] or MRI) to plan appropriate drainage.

SEVERE PERIANAL SEPSIS WITH SPREADING CELLULITIS

This is a life-threatening condition that is encountered almost exclusively in immunocompromised and diabetic patients, although occasionally in otherwise fit people. The infection is no longer confined to one compartment and it may be a spreading cellulitis or a necrotising soft tissue infection (see Chapters 4A and 21). Successful treatment depends on drainage of pus and excision of all dead tissue, combined with aggressive antibiotic therapy. Repeated examinations under anaesthesia are necessary to drain, or excise, areas that were previously deemed healthy but which have subsequently become involved. Faecal diversion by a colostomy is almost always necessary and aids in local sepsis control and hastens recovery.

In an older, debilitated patient, an indolent variant of severe perianal sepsis is occasionally seen. An apparently minor infection is drained, but healing does not occur. Although there is minimal cellulitis or necrosis, the wound slowly extends and the sphincter muscles, lying exposed within the disease cavity, are progressively destroyed. This distressing condition may occur during the last few days of life when pain relief is the only appropriate intervention. If more prolonged survival is likely, and the patient is fit for surgery, a defunctioning colostomy can be the best solution, for both control of the pain and management of the incontinence.

ANAL FISTULAE

Anal fistulae are classified based on the relationship of the track to the sphincters. The definition of *high* or *low* describes the height of the track as it traverses the sphincter muscles and not the position of the internal opening, which is, almost without exception, at the dentate line. More accurate classification defines the relationship of the track to the internal and external sphincters separately, and it is on this information, and the underlying pathology, that surgical treatment is based.[8] Most fistulae are either *intersphincteric* or *trans-sphincteric*. Preoperative MRI and endoanal ultrasonography are useful in delineating anatomy.

FISTULAE SECONDARY TO INTERSPHINCTERIC SEPSIS

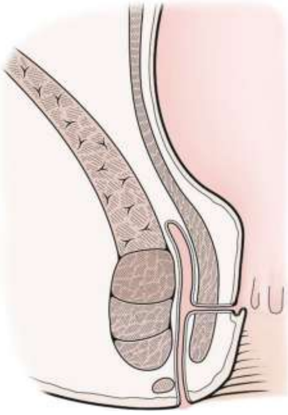
The most common anal fistulae are secondary to infection in an anal crypt gland. Pus collects initially in the intersphincteric plane. It may track to the anal verge to present as a perianal abscess or break through the external sphincter into the ischiorectal fossa (see Figure 15.10). The fistula is formed by spontaneous discharge or surgical drainage of an abscess, which creates another channel into the abscess in addition to the opening of the anal gland at the dentate line. A primary track has been formed, and continuing sepsis and poor drainage prevent healing. Bilateral circumferential tracking in a variety of planes (see Figure 15.9) is the aetiology of the posterior horseshoe fistula, with bilateral posterolateral tracks and external openings from a single internal opening (see Figure 15.11). The blind extensions and secondary tracks of complex fistulae are created by the tracking of pus and the spontaneous or surgical drainage of these collections. Assessment of the anatomy is difficult, and previous failed attempts at surgery for these fistulae result in increasing complexity. Referral of patients with high, and complex, anal fistulae to colorectal surgeons with a special interest is advisable.

FISTULAE SECONDARY TO OTHER PATHOLOGY

Anal fistulae can develop secondary to other infective, inflammatory and malignant pathologies, with the most common being tuberculosis and Crohn's disease. Fistulae also occur as a late complication of ileoanal pouch reconstruction surgery for inflammatory bowel disease.

Surgery of anal fistulae

Examination under anaesthesia, with gentle insertion of probes to define the fistula tracks, remains an important manoeuvre, despite increasing sophistication of preoperative and intraoperative imaging. Care must be taken not to create an additional internal opening by forcing the probe from a blind extension through the muscle and mucosa in the belief that there must be an opening in that position (Figure 15.13).

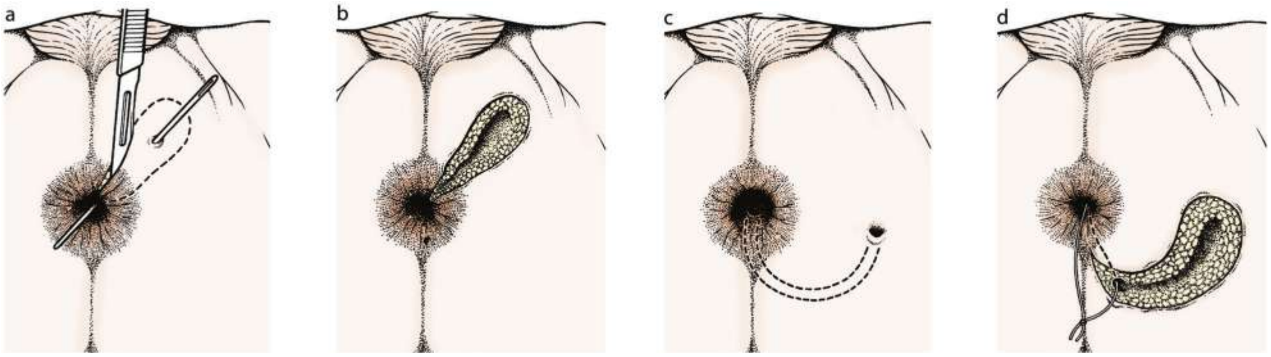


15.13 This low intersphincteric fistula has a secondary blind extension up into the supralevator compartment. The probe may miss the internal opening and enter this extension. The probe must not then be forced through the bowel wall at the blind end on the assumption that there must be an internal opening at this point. ⏎

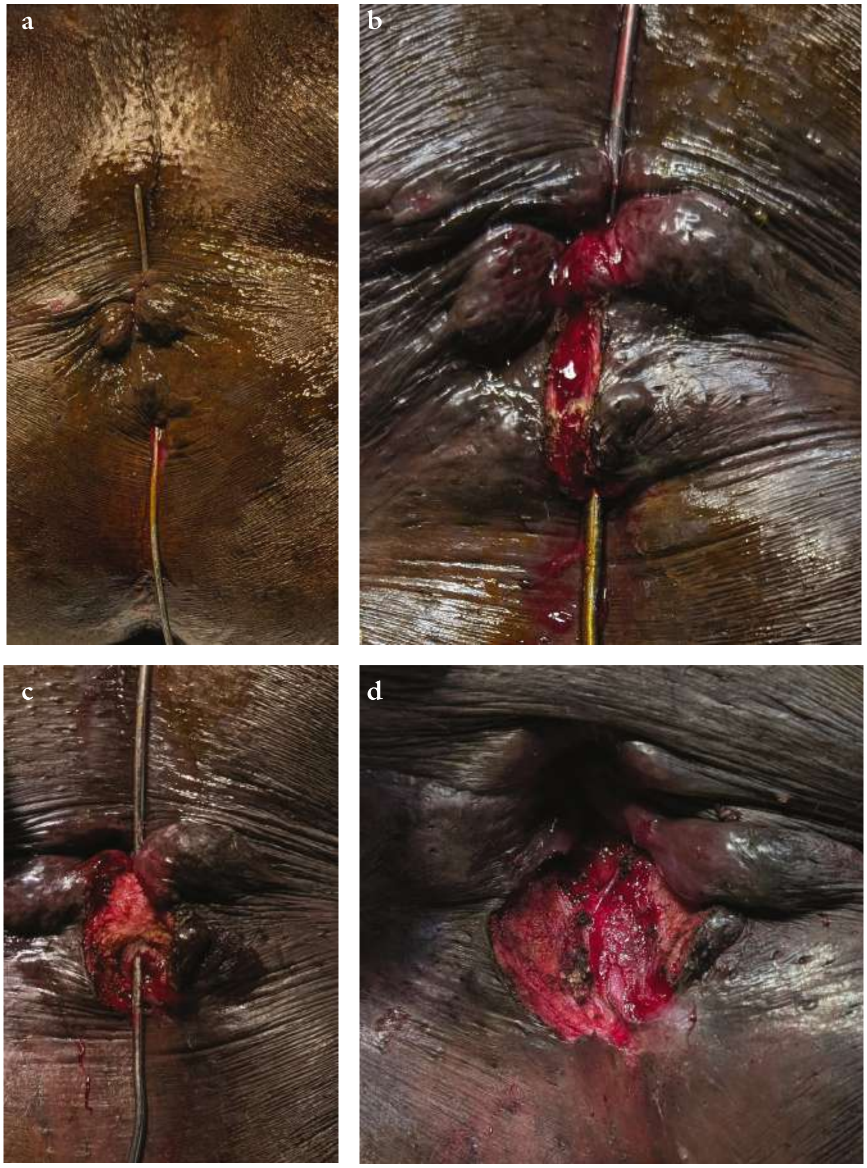
The knowledge that anterior tracks are commonly radial (whereas posterior ones are more often curved) and may be horseshoe in configuration, arising from a midline posterior opening (Figure 15.14), will make it easier to follow a track. Injection of either hydrogen peroxide or a dye into the external opening to produce a bubble of peroxide, or staining of the internal opening, respectively, are useful additional manoeuvres in some cases.

Laying open a fistula-in-ano (fistulotomy)

Laying open is the simplest and most effective treatment of a fistula. A grooved probe is passed along the track, onto which an incision is made through anoderm, skin, fat and any sphincter musculature distal to the track itself. The edges are trimmed to marsupialise the track and prevent bridging-over during healing (Figure 15.15). Most fistulae were treated in this fashion when it was believed to be safe to sacrifice the entire internal sphincter and the whole external sphincter below the anorectal ring. Later, there was increasing awareness of impaired continence after a spectrum of minor anal procedures in which only an apparently insignificant proportion of the anal sphincters had been sacrificed or damaged. There was also concern that adverse effects could be delayed for some years similar to what sometimes happens after obstetric sphincter damage. Increasingly, other methods, which minimised division of the sphincters and were originally employed only for high fistulae, were evaluated. Surgical opinion varies,[9,10] but all would agree that laying open remains a suitable technique for most intersphincteric fistulae when the proximal internal sphincter and the whole external sphincter can be preserved, and also for very low trans-sphincteric fistulae where less than one-third of the external sphincter is divided. Continence is a complex issue and, as discussed above, is not solely dependent on the integrity,



15.14 (a) An anterior track is usually straight and radial. (b) The low anterior fistula has been laid open. (c) A posterior fistula is often curved and may have bilateral posterolateral external openings from a single midline internal opening. (d) The external portion of the track has been laid open and the decision must now be made as to whether it is safe to lay open the part of the track that passes through the sphincter muscles. ⏎



15.15 Laying open a fistula-in-ano. (a) The tract is probed from the external opening to the internal opening. (b) The skin and subcutaneous fat are laid open. (c) The sphincter muscle distal to the tract can be divided in low fistulae. (d) The laid open tract is curetted to remove granulation tissue. ⏎

or otherwise, of the anal sphincters. Patients should therefore be warned preoperatively that there may be some deterioration in continence even when only a small portion of the sphincter is divided.

Setons

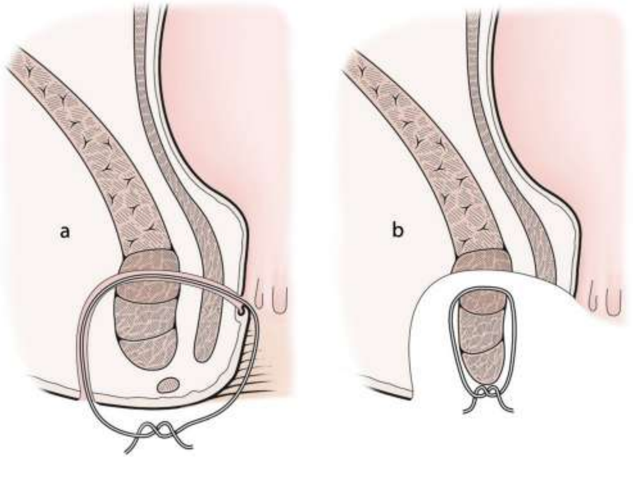
A seton is a thread that is introduced along the track of a fistula and left *in situ*. This is a very old method of treatment, both in Western and in traditional Indian medicine. Setons have been used in a variety of different ways, which determine the effect they have on the fistula track.[11] Setons have regained popularity recently and are currently used either as a loose draining seton or as a tighter cutting seton.

A fistula probe is first passed through the track. If a grooved fistula probe is used, a monofilament suture that will slide such as Prolene™ can be threaded along the groove through the whole track of the fistula. Suture material that will not slide along the groove can be delivered into position by first passing a Prolene suture. The chosen thread is then tied to it and drawn through the track. Alternatively, a probe with an eye is passed through the track and the seton is threaded through the eye and drawn through the track as the probe is removed.

Loose seton A loose seton ensures continuous drainage of any discharge and prevents premature closure of the external opening, which is the forerunner of recurrent sepsis. It is frequently a temporary measure to render a track more suitable for definitive treatment. A permanent loose, long-term seton may be the best treatment in some patients in whom more definitive surgery is likely to result in incontinence. As drainage is the most important goal, there should be no hesitation in extensively laying open any portion of the primary track, or extensions, outside the sphincters (Figure 15.16). A variety of materials have been used as a seton, the common ones being non-absorbable suture material, soft rubber slings and infant feeding tubes. The seton is passed through the track as described above, after which the two ends are knotted together outside the anus to form a loose encirclement (Figure 15.16a). Simple removal of a loose seton after some months of good drainage will result in definitive healing in some patients. In Crohn's disease, a loose seton may be placed temporarily to aid drainage of local sepsis and then removed after starting anti-tumour necrosis factor (TNF) therapy in order to allow healing.

Cutting seton A cutting seton is a definitive treatment of a fistula. A cutting seton works by slow division of the sphincters that it encircles, and the fistulous track becomes progressively 'lower' until finally the seton falls out. The advantage of the slow division of the sphincter is that only a small length of sphincter is divided at any one time and the portion sectioned is prevented from retraction by the intact sphincter above and below the seton. In addition, there is inflammatory tethering of the cut ends of the sphincter muscle. Healing occurs sequentially from above downwards with a narrow fibrous scar, which in turn prevents retraction of the fibres of the next portion that is divided. There are, therefore, theoretical advantages over simple surgical laying open of any trans-sphincteric track in which a significant portion of the sphincter mechanism must be divided. However, some surgeons argue that it merely prolongs the treatment in patients for whom laying open was safe from the onset and that, in those in whom it was unsafe, incontinence will not have been avoided.

If there is significant sepsis, a period of loose seton drainage should be employed. The patient is then re-examined under anaesthesia and the skin, subcutaneous ischiorectal fat and anoderm overlying the track are divided. The internal sphincter is usually divided, although a seton can also be used around it. The track has now been laid open, except where it passes through the external sphincter. The surgeon reassesses what proportion of the external sphincter would be sacrificed if laying open was to be completed and makes a final decision on management. As some distal migration of the track is seen, even with a loose seton, it may occasionally be judged to have become safe to divide the remaining sphincter below the track. When a cutting seton technique is used, a material such as silk (which causes an inflammatory reaction) is chosen, and this is tied snugly around the external sphincter muscle (Figure 15.16b). The seton will usually have cut through by 6–8 weeks. If, after this time, the seton is still *in situ*, a repeat examination under anaesthesia and replacement of the seton is indicated.



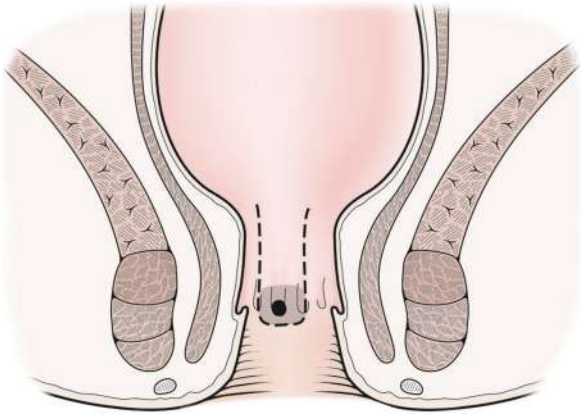
15.16 A trans-sphincteric fistula, which is not suitable for a simple laying open of the track. (a) A loose seton through the fistula secures good drainage of the sepsis. (b) The fistula can then be treated with a cutting seton. The internal sphincter, anoderm and perianal skin below the track have all been divided and the seton has been tied snug around the external sphincter. ⏎

Advancement flaps

Advancement flaps obliterate the internal opening and allow the fistula to heal. The surgery is technically demanding and performed through the anus. The position of the internal opening dictates the optimal position for surgery; the prone jack-knife position is more suitable for a rectovaginal fistula and the lithotomy position is more suitable for a posterior fistula. A flap of mucosa with underlying internal sphincter, which ensures both blood supply and strength, is mobilised and advanced down to cover the internal opening (Figure 15.17). An alternative is a flap advanced up rather than down. Excellent results can be obtained, but often only by surgeons who perform these operations frequently.

Track excision

A variety of techniques are based on the concept of excision of part, or the whole length, of the mature fistula tract, removing just the core of sphincter muscles through which it passes. This is a difficult operation,



15.17 A flap of mucosa, with the underlying internal sphincter, is mobilised and brought down to cover the proximal track The shaded area, which includes the internal opening, is excised. ⏎

and the approach can be either from outside the sphincters or via the intersphincteric plane. Success is probably dependent on obliteration of the internal opening and eradication of residual intersphincteric sepsis, rather than complete excision of the track.

DEFINITIVE TREATMENT FOR FISTULA WITHOUT SPHINCTER CUTTING

Fibrin glue can increase the percentage of fistulae that will heal after removal of a seton to around 60%. All sepsis must have been eradicated. Therefore, a period of loose seton drainage should always precede treatment if there is any significant sepsis. The seton is removed and granulation tissue curetted from the track. The nozzle of the injection kit is introduced into the external opening, and the two solutions of fibrinogen and thrombin are injected simultaneously until a bleb appears at the internal opening. The two solutions mix within the fistulous track and set. The anal retractor should be left in place for around 10 minutes until the bleb solidifies, as it is this plug at the internal opening that is critical for success. If treatment is unsuccessful and the fistula recurs, the procedure can be repeated.

A *fistula plug* can be sutured into the fistula track to occlude it. The plug material acts as a scaffold and tissue grows through it to occlude the track. Success rates are about 50%, but are very variable between reported series.[12]

Ligation of the intersphincteric tract (LIFT) is a procedure by which the intersphincteric plane is entered by sharp dissection and the tract is identified, divided and ligated, along with curettage of the rest of the tract.

Ablative procedures with laser or radiofrequency can also be used in simple, low intersphincteric or trans-sphincteric tracts that do not have active pus discharging or an abscess. The above-mentioned procedures are not as effective as a fistulotomy, but are good adjuncts in situations where pre-existing sphincter weakness exists or is expected.

CROHN'S DISEASE OF THE ANUS: 'CROHN'S ANUS'

Anal tags, anal fissures, recurrent anal sepsis and fistulae-in-ano are common in patients with Crohn's disease. In some patients, the anal pathology is incidental and unrelated to their Crohn's disease and no histological evidence of Crohn's inflammation is found in local biopsy specimens. Treatment follows the same principles as outlined above. In patients whose anus is involved in the Crohn's disease process, Crohn's proctitis may, or may not, coexist. Intensive medical treatment, with antibiotics and immune modulation, is frequently very effective, at least in the short term. It is important to recognise the aetiological factors and pathogenesis of fissures and fistulae due to Crohn's disease. A Crohn's fissure is a deep inflammatory ulcer and not a mechanical tear, and a Crohn's fistula has granulomatous inflammation along the track in addition to bacterial infection. Medical management is the primary treatment and the objectives of surgery are to adequately drain local sepsis, prevent recurrent sepsis using drainage setons and obtain tissue to establish diagnosis, if required.

A diversion colostomy may bring temporary relief, but the disease often recurs after stoma reversal. A permanent colostomy, without proctectomy, does not prevent the continuing perineal sepsis.

Many patients eventually require proctectomy, either for recurrent sepsis or for incontinence, which may in part be due to iatrogenic sphincter damage during attempts at surgical treatment. The prognosis is worse in patients who have rectal involvement, particularly if there is an anorectal stricture or supralevator induration. Healing of the perineum after a proctectomy for anorectal Crohn's may be very protracted. Medical treatment of the underlying Crohn's, particularly anti-TNF therapy, is often effective, but sepsis should be under control before starting immunosuppressive drugs.

SURGERY FOR FAECAL INCONTINENCE

Conservative treatment for faecal incontinence will be the best option in many patients. Loperamide is used to reduce stool frequency, and the more solid stool also results in easier control. Biofeedback exercises help to build the strength of the external sphincter muscles and improve their coordination. Suppositories, enemas or irrigation can be used to ensure the rectum is empty and prevent passive leakage of rectal contents. Any underlying pathology causing diarrhoea or reduced rectal capacity, such as malignancy or colitis, should be considered and treated. With the exception of acute sphincter injuries, surgery is usually considered only once conservative measures have been tried and failed.

Unfortunately, many patients with incontinence cannot be helped by sphincter surgery or sacral nerve stimulation. If conservative measures have also failed, a colostomy may be an acceptable solution; an anus with no functioning sphincter is, in essence, a perineal colostomy to which no stoma bag can be attached.

Careful preoperative sphincter assessment, both anatomical and physiological, is essential prior to any surgery for incontinence. Anatomical disruption of the external sphincter can be repaired with good short-term results, but longer follow-up shows deterioration in continence over time. Surgical repair of the internal sphincter is less satisfactory. Poorly functioning but intact sphincters are also a common cause of incontinence. Operations to shorten lax sphincters by plication or to increase pelvic floor support by approximation of the levator muscles have generally been disappointing. Plication of the levators behind the anus has the added theoretical advantage of restoring the anorectal angle, but the functional benefit is often only temporary.

The decision to offer sphincter surgery is relatively straightforward if the patient has a complete external sphincter disruption with major urge incontinence developing at the same time. However, many patients have only impaired continence, often developing some years after the sphincter injury. Investigations may confirm a partial tear. If a surgical repair is undertaken but breaks down, the patient may have worse continence than the preoperative level of continence. The patient must be aware of the risks and limitations of surgery.

EMERGENCY SPHINCTER REPAIRS

Emergency sphincter repairs are most commonly performed by obstetricians as part of the deeper perineal muscle repair of an episiotomy or tear in childbirth. Operative conditions are seldom ideal, and the extent of the damage to the external sphincter may not be appreciated. Despite this, many heal satisfactorily.

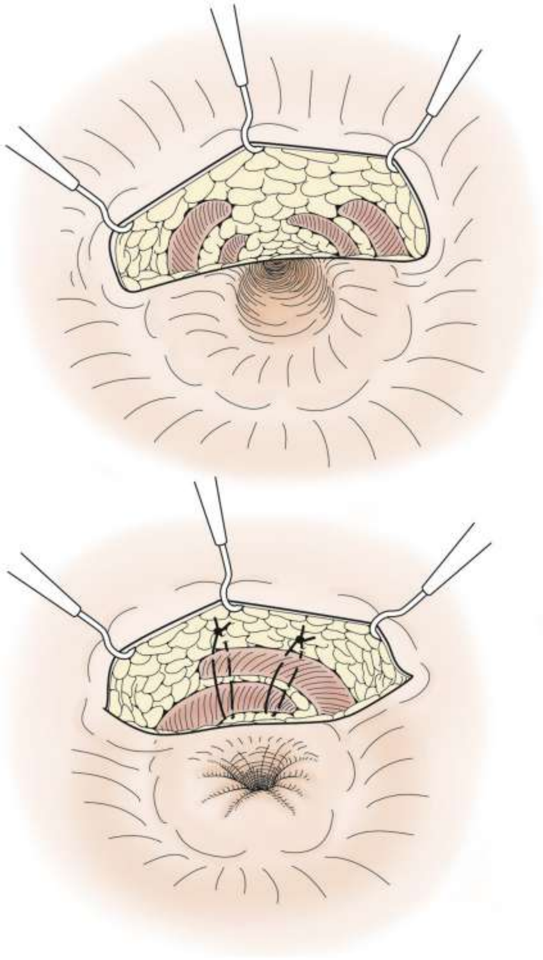
When major sphincter damage is associated with a perineal tear that extends to the anal verge and into the anorectum, the severity of the injury is recognised at delivery. A general surgeon with experience in perineal surgery should be involved in the primary repair whenever possible. The repair should be undertaken under optimal operative conditions some hours after delivery. Working from the vaginal aspect, with the patient in the lithotomy position, all layers, starting with the anorectal mucosa, are identified, cleaned of faecal contamination and anatomically approximated. A defunctioning stoma will give the best chance of good healing if the anorectal mucosa is torn, but the patient may be reluctant to consider this. Similar principles apply to traumatic sphincter damage from perineal impalement injuries.

The occasional patient presents several days or weeks after delivery with an obvious sphincter disruption as part of an episiotomy that has broken down, and this may even be associated with the development of an anovaginal or rectovaginal fistula. Secondary repair should be delayed for some months, as all the tissue will be too friable for a satisfactory repair at this stage. If there is a significant rectovaginal fistula or complete incontinence, faecal diversion with a temporary colostomy may be required in the interim.

ELECTIVE SPHINCTER REPAIR

Elective repair of an external sphincter defect is most often undertaken months, or years, after major sphincter damage in women sustained in childbirth or after anal surgery in males and females. Good operative conditions are essential, with the patient in either the lithotomy or the prone jack-knife position.

The incision is made just outside, and parallel to, the anal sphincters at the site of the defect (Figure 15.18). Dissection proceeds in the extrasphincteric plane until the sphincters are defined. The divided sphincter ends will have retracted circumferentially, but will also be displaced laterally from their normal position. The external sphincter twitches when touched with diathermy, whereas there is no response from perineal scar tissue or the internal sphincter. This sign can be very useful in a difficult operation. Dissection is continued to mobilise the external sphincter over about one-third of its circumference. Any fibrous connection between the disrupted muscle fibres is divided, but not excised. An overlap repair is then performed with non-absorbable Prolene or a long-acting dissolvable suture (Figure 15.18). An infected haematoma is a potential cause of breakdown of the repair, and both meticulous haemostasis and antibiotic prophylaxis are important. A repair will often have changed the orientation of the skin incision from transverse to longitudinal as the anatomical configuration of the perineum is restored, and the skin should be closed in the axis in which it lies most naturally. A small portion of the wound should be left



15.18 External sphincter repair. A curved incision is made just outside the pigmented perianal skin. The ruptured ends of the sphincter are identified in the fat, mobilised and repaired with overlap. ⏎

open to facilitate free drainage of any serosanguineous collection. Postoperatively, antibiotics and stool softeners are continued.

Lateral defects in the external sphincter are less common than anterior defects and are more often iatrogenic in aetiology. Repair is complicated by the lateral innervation of the sphincters, and nerve damage during the dissection is a risk. A nerve stimulator to identify the neurovascular bundle may be helpful.

Internal sphincter repair

Internal sphincter repair is often unsatisfactory and is seldom attempted in isolation. In major disruption of both sphincters, it is usually not possible to identify the internal sphincter separately and, therefore, the whole sphincter complex may be overlapped as a single unit. However, if the internal sphincter is identified as a separate entity, it is then preferable to repair it separately. It is a thin sheet of muscle, which can be sutured with a continuous suture. Prolene sutures so close to the anoderm cause irritation, and a long-acting absorbable suture is preferable.

SACRAL NERVE STIMULATION

Sacral nerve stimulation uses a permanently implanted pulse generator, similar to a cardiac pacemaker, to provide electrical stimulation of the S3 or S4 nerve root. Although a number of potential mechanisms of action have been suggested, it remains unclear precisely how sacral nerve stimulation works. It can be effective in patients with faecal incontinence for a variety of reasons, including those with unrepaired internal or external sphincter injuries.[13] It has also shown promise in the treatment of severe evacuatory disorders.

In order to assess the suitability of a patient for this procedure, a trial period of temporary stimulation is carried out. With the patient in the prone position, under general or local anaesthesia, a percutaneous electrode is inserted through the S3 or S4 sacral foramen. Electrical stimulation is applied to the electrode and contraction of the pelvic floor or plantar flexion of the halux confirms stimulation of the S3 nerve root. The electrode is connected externally to a reusable pulse generator, which must be carried by the patient for the 2- to 3-week trial period. In the 75% of patients whose symptoms are controlled or markedly improved, a second operation is carried out to place a permanent electrode, attached to an implanted pulse generator, which is usually implanted in the buttock.

ARTIFICIAL ANAL SPHINCTERS

The following two techniques are associated with defecatory difficulties and late failure and, especially since the advent of sacral nerve stimulation, are rarely performed:

1. A *stimulated graciloplasty*, in which a gracilis muscle is wrapped around the anus, can restore continence. An implantable electric stimulator is necessary, as, otherwise, the wrap of fast-twitch fatiguable fibres functions merely as a stenosing device.
2. *Artificial implantable mechanical sphincters* are beset with problems. Infection and extrusion occur, and the high pressures required to maintain continence can cause ischaemic damage to the anorectal mucosa.

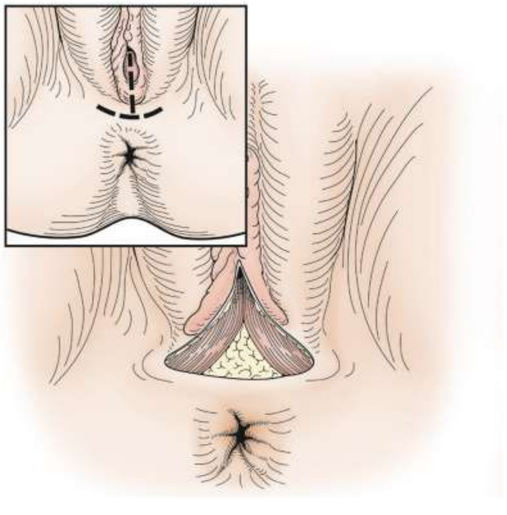
OTHER PERINEAL REPAIRS

Levatorplasty

Levatorplasty consists of plication of the levator muscles either behind (*posterior levatorplasty*) or in front of (*anterior levatorplasty*) the anus. The approach is through the extrasphincteric plane. Two or three non-absorbable interrupted sutures are placed to approximate the muscle. The operation in isolation is generally disappointing in the long term and is now most often employed in combination with a sphincter repair.

Rectocele repair

A rectocele is a tissue defect in the rectovaginal septum, and the rectum herniates into the vagina, above the sphincters. The initial disruption is almost exclusively associated with childbirth and, although it occurs in isolation, it is also seen in association with a complete or partial anterior sphincter disruption. Many large defects are symptomless, but some patients complain of a lump in the vagina on straining and symptoms of obstructive defecation. Surgical opinion varies as to the benefit of repair. Repair can be undertaken transvaginally, transanally, through the perineum or from the abdomen. A perineal approach is illustrated in Figure 15.19. A transverse perineal incision is made immediately posterior to the vagina and the plane dissected deep to the posterior vaginal wall as far as the upper extent of the rectocele. The vaginal wall is then divided vertically and the dissection carried laterally to expose the extent of the rectocele.



15.19 Repair of a rectocele. A transverse incision just posterior to the vagina is later extended by a vertical division of the posterior vaginal wall. The rectum is pushed posteriorly, and deep sutures are used to draw the puborectalis portion of the levators across between the vagina and rectum. The muscle is easier to feel than see, as it is covered with fascia and lying within fibro-fatty tissue. ⏎

Simple plication of the posterior vaginal musculature or rectal wall is employed by some surgeons, but most favour some form of additional support between the rectum and vagina. Ideally, the rectovaginal septal defect is defined and repaired. Unfortunately, it cannot normally be identified as a layer suitable for a strong sutured repair, and extra strength can be obtained only by deep sutures to draw the levator muscles into the midline from either side (Figure 15.19). Vaginal narrowing can be caused by a levatorplasty if too much tissue is drawn in and approximated. The vaginal mucosa and perineal wound are then closed, and a vaginal pack for local pressure reduces the risk of a haematoma. Mesh is avoided because of the risk of infection, but can be used in the rectovaginal septum for support where additional pathology has made it more appropriate to perform the rectocele repair from above.

RECTAL PROLAPSE

The number of operations designed to treat rectal prolapse is a reflection of the difficulties that surgeons experience in securing good long-term results. Both abdominal and perineal approaches to this condition have been extensively explored.

ABDOMINAL RECTOPEXY

An abdominal approach has a lower incidence of recurrence. However, it is a more major procedure for older people, even when undertaken laparoscopically, and, in younger patients, the increased risk to the autonomic nerves and sexual function must be considered. The rectum is mobilised out of the sacral hollow and fixed to the pelvic brim with non-absorbable sutures. Success is increased by adding a high anterior resection to the operation – a *resection rectopexy*. Mesh placed behind the rectum has generally fallen out of favour because of infectious complications and evacuatory dysfunction. Alternatively, after dissecting the rectum only in the anterior plane, mesh is attached to the rectum anteriorly and then anchored proximally to the sacral brim. There have been significant concerns surrounding mesh-related complications, including erosion into the vagina, after mesh rectopexy in recent years. This has led to avoidance, or at least a more judicious approach to the use of mesh. Some surgeons now advocate using biological rather than synthetic mesh, although the evidence of its superiority is not conclusive and the cost is significantly higher.

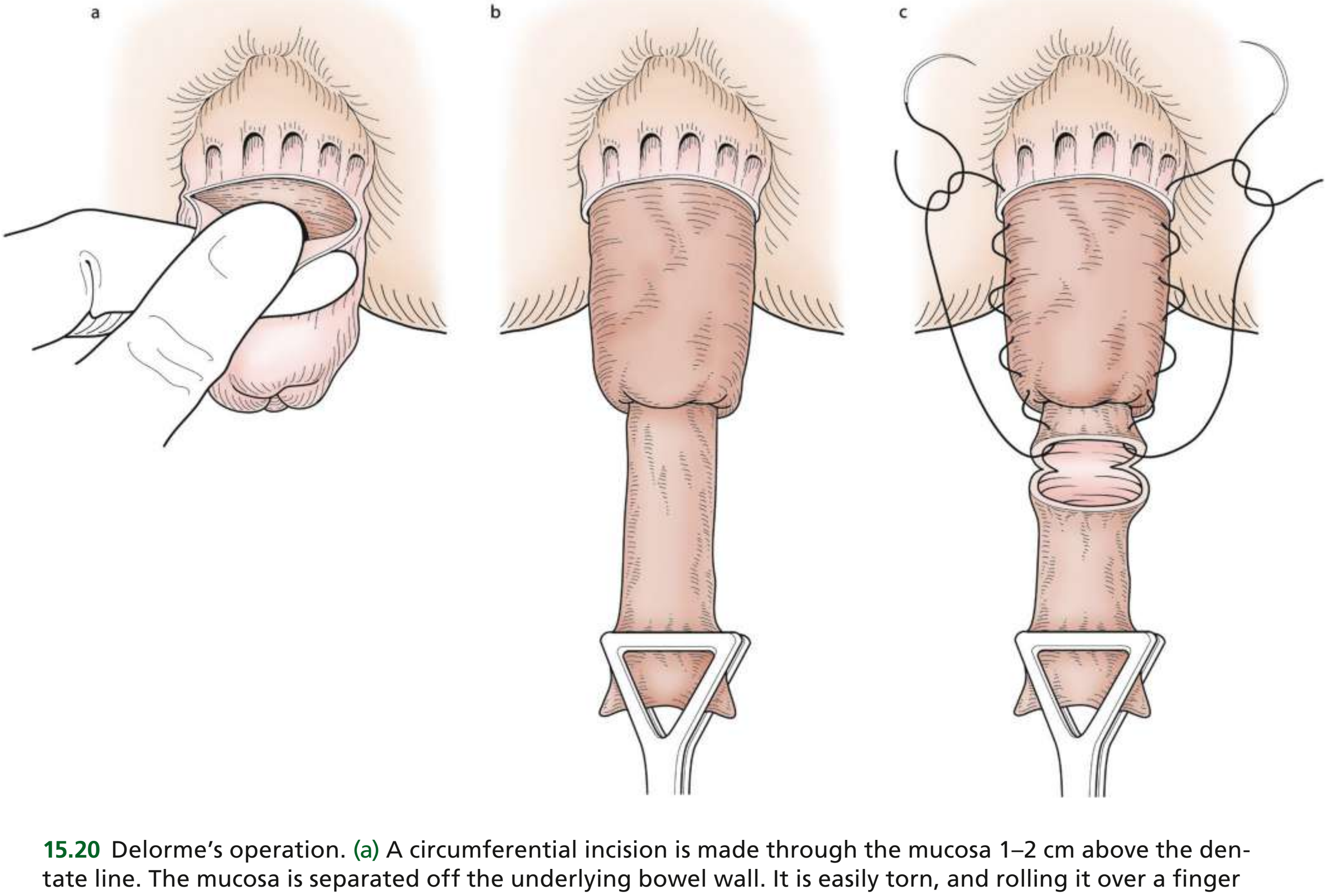
PERINEAL APPROACHES

Perineal surgery for rectal prolapse is usually well tolerated even by much older people. Postoperative pain is minimal, and most patients are fit to be discharged home within a few days.

The operations are performed in the lithotomy position. The prolapse is encouraged to prolapse out through the anus to its full extent by gentle retraction of the rectal wall. A series of six to eight sutures are passed both through the skin at the anal verge and through more distant perineal skin. Once tied, they will evert the anal canal and form a simple means of retraction. Alternatively, a self-retaining ring retractor with skin hooks, as described above (see 'General technique'), may be preferable. A dilute solution of adrenaline (1:400,000) is injected submucosally into the outer tube of the prolapse and the mucosa incised circumferentially with diathermy 1–2 cm above the dentate line for a Delorme's operation and 1 cm or so higher for an Altemeier's operation.

Delorme's operation

The mucosa from the whole prolapsed segment of bowel is removed, followed by reattachment of the proximal mucosal edge, with the underlying muscle of the bowel wall, to the initial circumferential incision just above the dentate line. Diathermy dissection in the adrenaline-filled submucosal plane can be relatively bloodless. Initially, the detached mucosa is lifted in forceps or rolled over a finger to display the plane for dissection (Figure 15.20a). The dissection is usually commenced anteriorly and the plane followed around each side to the posterior aspect of the prolapse. Difficulty will be encountered if the initial circumferential incision is not completed posteriorly, as the tethered mucosa will fail to lift and will tear. As the dissection reaches the apex of the prolapse, the mucosa forms a sleeve, which can be retracted to facilitate dissection on the inner surface of the prolapse (Figure 15.20b). Further adrenaline can now be injected into the submucosal plane of the inner tube.



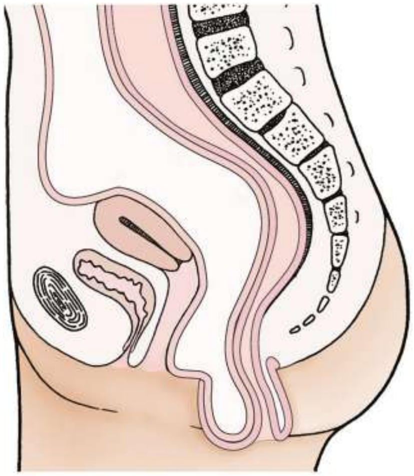
15.20 Delorme's operation. (a) A circumferential incision is made through the mucosa 1–2 cm above the dentate line. The mucosa is separated off the underlying bowel wall. It is easily torn, and rolling it over a finger may be gentler than holding it with forceps. (b) The mucosa forms a tube once the dissection reaches the apex of the prolapse. (c) The lateral plication sutures include several bites of prolapsed muscle wall. In this diagram, they are also forming the initial mucosal apposition sutures. (The anterior suture has been omitted from the drawing.) ⏎

When no further mucosa can be prolapsed, the dissection is complete.

The first four sutures for mucosal apposition should also pass through multiple points in the denuded muscle of the bowel wall to plicate it (Figure 15.20c). It is important that mucosa does not retract, and the first three sutures should be in place before the mucosal tube is completely divided. Once all four sutures are in place, they are tied and the muscle tube is reduced back inside the anus as a bulky ring. The ends of these initial sutures are left long and held in forceps so that retraction can facilitate the positioning of later sutures. A further 8–12 sutures complete the mucosal apposition. Each suture should include the muscle immediately deep to the mucosa for adequate strength, but no further deep plication is attempted. An absorbable suture that retains tensile strength for a few weeks is suitable, and Vicryl® is commonly used. The first sutures, which include the muscle plication, need to be heavier and stronger than subsequent sutures, which are solely for mucosal apposition. The anal verge retraction sutures are cut, or the skin hooks detached, and the suture line retracts within the anus.

Altemeier's operation

Altemeier's operation is a perineal rectosigmoidectomy. The initial steps of the operation are similar to Delorme's operation, but the circumferential mucosal incision is deepened through the full thickness of the bowel wall. This division is safely above the anal sphincters if the initial mucosal incision is placed correctly 2–3 cm above the dentate line. The prolapsed rectum then unfolds and is drawn out further through the anus as a single full-thickness tube along with its mesorectum. Anteriorly, a pocket of peritoneum in the rectovaginal pouch is also prolapsed (Figure 15.21). It must be entered and any small bowel loops replaced into the abdomen. Posteriorly, the mesorectum is drawn down with the rectum, and is separated from it by multiple ligations of mesorectal vessels close to the rectal wall. The dissection is continued until further bowel is reluctant to prolapse. An initial division of part of the circumference of the bowel allows the first sutures of the anastomosis to be secured, as it is important at this stage that the bowel does not retract up into the pelvis. In contrast to a Delorme's operation, the sutures are not merely to achieve a mucosal apposition, but to form a full-thickness low coloanal anastomosis.



15.21 Anteriorly, a rectal prolapse includes a prolapsed pouch of Douglas. An understanding of this is essential in an Altemeier's operation. ⏎

POSTOPERATIVE PROGNOSIS

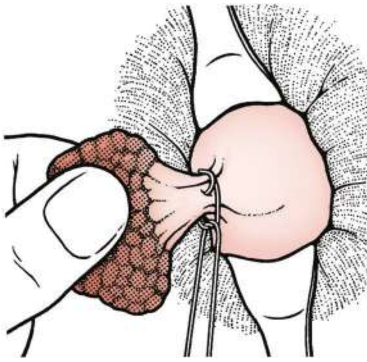
Patients with rectal prolapse often have poor anal sphincters. The prolapse itself causes further stretching and laxity, and most patients are at least partially incontinent preoperatively. Some improvement can be expected with surgery, and the increased perianal muscle bulk after a Delorme's operation is an added advantage. A perineal operation can only deal with bowel that is already able to prolapse, and a high recurrence rate has disheartened some surgeons. However, the operation is well tolerated by older patients and may be repeated a few years later if required.

PERINEAL APPROACHES TO THE RECTUM

The rectum may be approached surgically from the perineum and these approaches are discussed below. For some pathologies, a combined abdominal and perineal approach is required, and these procedures are described in Chapters 13 and 14.

TRANSANAL APPROACHES

A transanal approach is routinely used for endoscopic snare removal of benign polyps throughout the colon. In addition, direct surgical access through the anus allows surgical excision of benign tumours in the rectum. It may be possible to deliver a mobile polyp out through the anal sphincters (Figure 15.22). A higher, more broad-based villous lesion will have to be removed *in situ* through a proctoscope or anal bivalve retractor. Access is inevitably restricted, as excessive anal dilation must be avoided. Elevation of the lesion off the underlying muscle by a submucosal injection of 1 in 400,000 adrenaline may be helpful in reducing bleeding and in identifying the optimal plane. A



15.22 Excision of a rectal polyp. It may be possible to prolapse a polyp on a stalk out of the anus for resection. ⏎

full-thickness excision can achieve complete removal of even a T2 rectal cancer, but the possibility of lymph node metastases will not have been addressed. This makes the technique unsuitable except in limited circumstances (see Chapter 14). A mucosal defect is usually closed with absorbable sutures, and it was believed that this was mandatory after a full-thickness excision until it was shown to be unnecessary if the defect was below the peritoneal reflection.[14]

Transanal endoscopic microsurgery

Transanal endoscopic microsurgery (TEMS) uses a large operating proctoscope through which a binocular microscope can be introduced.[15] Excellent views of the rectal mucosa can be obtained up to around 15 cm from the anal verge. The proctoscope is positioned to give a view of the rectal lesion and then fixed in position using an adjustable clamp to attach it to the operating table. The microscope is inserted and an insufflator attached. The proctoscope contains additional ports, which can be used to introduce specially designed graspers, suction, diathermy or ultrasonic dissecting instruments as required. The technique has similarities to laparoscopic surgery. The surgery performed is the same as that carried out through a traditional transanal approach, but with a better view, allowing a greater degree of precision and access to lesions higher in the rectum than would otherwise be possible. It must also be remembered that the same concern regarding possible lymph node metastases applies, and many cases are technically possible but oncologically unsuitable. Considering small numbers of patients in whom this approach is suitable and the steep learning curve to achieve expertise in this technique, it is best done by surgeons with training, expertise and a special interest in this technique. The equipment is expensive and not every colorectal surgeon will wish to acquire the skills to perform these operations.

The *transanal minimally invasive surgery* (TAMIS) system allows the use of standard laparoscopic instruments through a modified laparoscopic single-port access platform. This makes the procedure more feasible for a general surgeon.

POSTERIOR APPROACHES

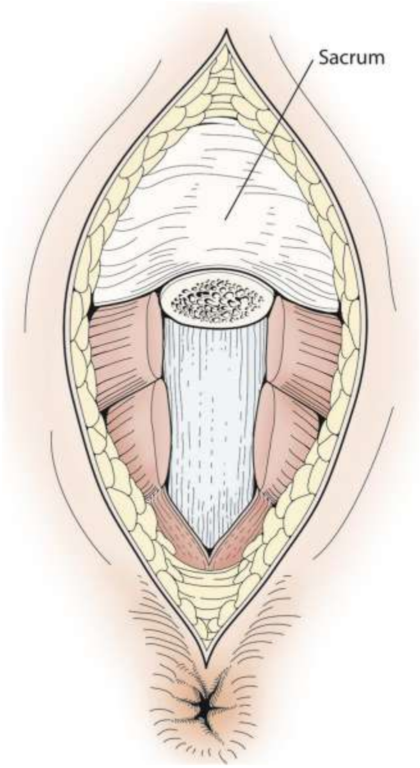
The posterior approaches to the rectum, the posterior pelvic floor and the retrorectal space may be posterolateral (between the sacrum and the pelvis), transverse (between the anus and the coccyx) or through the midline posteriorly. All these approaches share the problems of limited access, potential for autonomic nerve damage and transgression of lymphatic channels in the mesorectum, making them unsuitable if malignancy is suspected. Additionally, when a posterior approach is combined with anal sphincter division and repair, at the end of the procedure, breakdown of this can lead to incontinence. If the anococcygeal ligament must be divided for access, it should be reattached or contraction of the puborectalis sling will simply displace the anus forwards. All these factors have made the posterior approach less preferred, but it remains a good approach to access the retrorectal space for excision of benign lesions.

Kraske or sacral approach

This is a midline posterior approach to the rectum. The skin incision is deepened onto the surface of the coccyx and lower sacrum. The muscle attachments to the sides of the coccyx are freed, and the anococcygeal raphe incised in the midline from the tip of the coccyx to the external sphincter (Figure 15.23). The coccyx is excised and, if access is still insufficient, the fifth and fourth sacral vertebrae can be partially removed in the midline by a bone nibbler. The third sacral nerve should be preserved. Waldeyer's fascia is then incised and the posterior mesorectum exposed. After completion of surgery, Waldeyer's fascia is closed and the anococcygeal ligament and the muscular attachments to the coccyx are approximated.

York Mason approach

The patient is placed in the prone jack-knife position and a posterolateral incision is extended up from the anal verge. The bowel is incised in line with the skin incision, from the anal verge upwards, so that the anus and lower rectum can be opened . The divided anal sphincters and the bowel wall are resutured on completion of the procedure. Excellent exposure of the anterior rectum is obtained,[16] but, with the development of more sophisticated transanal techniques, there are now few indications for this operation.



15.23 The Kraske posterior approach. The muscles have been separated from their attachments to the coccyx, the anococcygeal raphe has been incised in the midline and the coccyx has been removed. Waldeyer's fascia is exposed. ⏎

Posterior sagittal anorectoplasty

Posterior sagittal anorectoplasty is the standard paediatric surgical operation for the reconstruction of anorectal malformations. The patient is catheterised per urethra and placed prone with the pelvis elevated. The centre of the external sphincter is determined with a transcutaneous electrical muscle stimulator. Starting at this point, a midline sagittal incision is made, the length of which is determined by the complexity of the defect, but may be extended as far as the coccyx. Anteriorly, the incision is carried through the external sphincter to expose the fistulous connection. All tissue is divided exactly in the midline to avoid damage to important nerves. The rectum is opened and separated from the urinary tract or vagina. It is then mobilised and tapered to allow it to be placed within the limits of the reconstructed external sphincters.

PERINEAL EXCISION OF THE RECTUM

This is usually a suboptimal operation for any malignant rectal lesion, as adequate excision of the lymphatic drainage is currently not possible without abdominal access.

Rectal excision for benign disease can be undertaken solely from the perineum when, for example, the colon has already been excised, the patient has an end colostomy and there is no other reason to re-enter the abdomen. The intersphincteric plane is entered at the anal verge and the mobilisation is continued as a close rectal dissection to remove the bowel but to leave the anal verge skin, the external sphincter and the pelvic floor musculature intact, in addition to retaining the mesorectum *in situ*. This approach is suitable for a short rectal stump, but there is a risk of damage to small bowel loops adherent within the pelvis.

SURGERY FOR MALIGNANT AND PREMALIGNANT ANAL DISEASE

An anal cancer may be either an adenocarcinoma or a squamous cell carcinoma. The behaviour and management of the two tumours are very different. A preoperative biopsy for histology is therefore essential prior to any planning, as differentiation is not possible clinically.

An *adenocarcinoma* arising in the mucosa of the upper anal canal and anorectal junction behaves like an adenocarcinoma of the rectum and the treatment is primarily surgical. However, direct extension will occur early into the sphincter muscles and, to obtain adequate clearance, an abdominoperineal excision is usually inevitable, except in very early tumours above the dentate line, which are still mobile on the external sphincter (see Chapter 14).

Squamous cell carcinomas arising from the squamous epithelium of the lower anal canal have a different behaviour and pattern of spread. Treatment is now primarily by chemoradiotherapy, and surgery is confined to a diagnostic biopsy and, possibly, construction of a defunctioning stoma during treatment, if local symptoms are severe. Those cases that show only a partial response to chemoradiotherapy or relapse after completion of treatment may require salvage surgery consisting of an abdominoperineal excision (Chapter 14). An inguinal node clearance may also be indicated as a salvage procedure (Chapter 16). The disease itself, or the treatment, may destroy the anal sphincters and, in these patients, a permanent left iliac fossa end colostomy is usually the best solution.

Anal intraepithelial neoplasia (AIN) appears as a patch of abnormal epithelium at the anal verge or in the perianal skin. Clinical suspicion is confirmed by biopsy or complete excision if the area is small. Mild degrees of dysplasia can be monitored over time, but severe dysplasia, amounting to carcinoma *in situ*, should be excised or ablated, as progression to invasive carcinoma is a significant risk.

PILONIDAL SINUS SURGERY

This apparently minor condition can present the surgeon with major challenges. The initial pathology is of one or more tiny deep midline pits in the natal cleft, which connect with a granulation tissue-lined cavity lying in the subcutaneous fat and containing loose hairs. Recurrent infections occur in this cavity, which later extends under apparently normal skin, both in the natal cleft and laterally into one or both buttocks. Minor infections may settle on antibiotics, but if an abscess develops it will discharge or require drainage. However, the underlying disease remains, and repeated episodes of infection are likely.

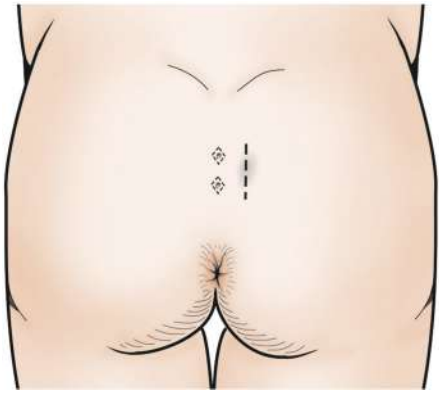
Deroofing all sinuses and awaiting healing of the granulating wound is a long process. Excision and primary closure is another option when the disease is confined to the midline, but if the closure breaks down, a larger defect is left to granulate. With both techniques, recurrence is common, as hair can later grow into the midline scars.

Two flap techniques, which avoid a midline scar and have proved very successful for advanced pilonidal disease, are described below.[17,18] They are unnecessarily extensive for minor disease, for which a modification and simplification of the original Bascom procedure is more appropriate.

Modified Bascom procedure

The modified Bascom procedure is an ideal operation when there are no midline unhealed wounds, abscesses or scars. The patient lies prone and local infiltrative anaesthesia is satisfactory. The buttocks are strapped apart. Each pit is excised with the pointed No 11 blade, removing a diamond-shaped piece of skin, no larger than a rice grain, but the excision should extend deep for 2–3 mm to include the epithelialised portion of the pit. A 2–3 cm incision is then made 2 cm from the midline alongside the pits, on the side of any previous infection. A probe introduced into a pit may act as a guide if none is apparent (Figure 15.24). This incision serves three functions. Firstly, it is used to enter the pilonidal sinus system and curette out all hairs and infective granulation tissue. Secondly, the midline skin is released through the incision from its tethering to the post-sacral fascia, and the depth of the natal cleft is reduced. Thirdly, as the incision is left open, it relieves any tension on the subsequent closure of the pits.

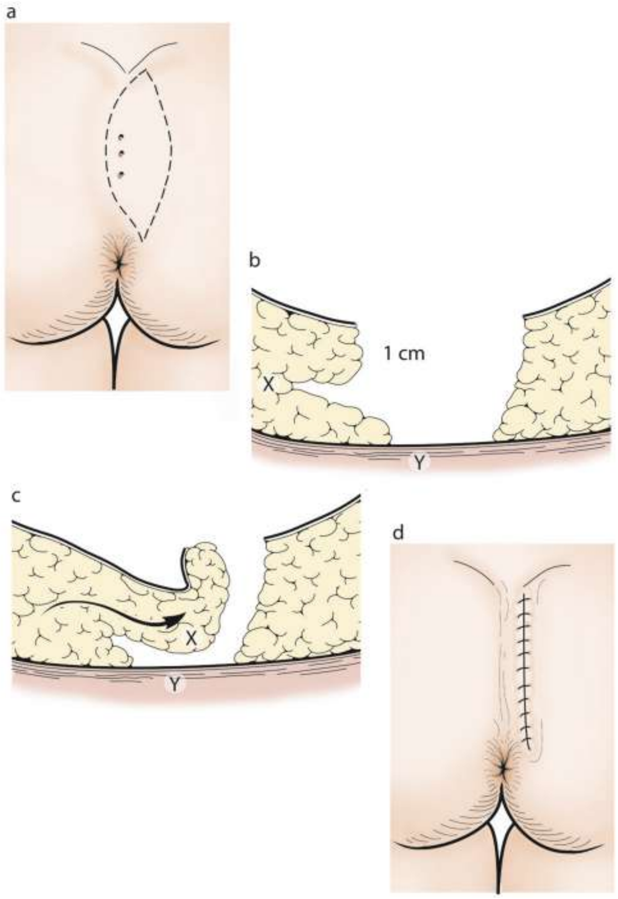
The buttock strapping is then removed to relieve tension and each pit excision is closed with 5/0 Prolene. Midline scarring may be minimised if the suture is introduced 1 cm lateral to the pit, continued around the pit in the subcuticular plane, brought out close to its initial insertion and tied. The remaining steps described in the original Bascom procedure, in which a fibro-fatty flap is rotated under the midline skin, are omitted. An antiseptic-soaked wick is simply tucked into the lateral wound so that it lies under the midline and is removed after 48 hours. A course of antibiotics is given, the pit closure sutures are removed at 1 week and healing of the lateral wound is usually complete by 2 weeks. Obliteration of the pits is achieved and each incision leaves only a midline wound of a couple of millimetres in length. If there is recurrence and more radical surgery is indicated, the scars are within the area of skin that will be excised in either of the flap procedures described below.



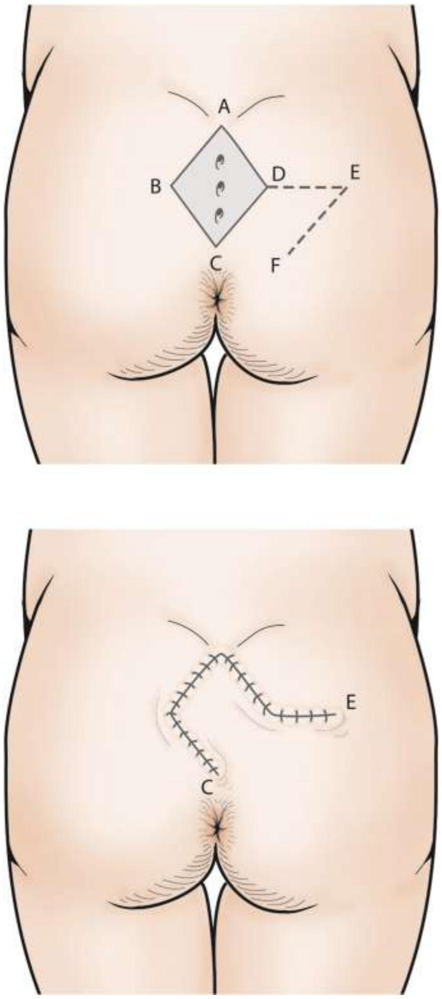
15.24 A Bascom procedure. The lateral incision is alongside the midline cleft and is over the scar of any previous lateral abscess. Each pit is excised with a 'diamond' of skin, which must include all the epithelialised portion of the pit. The pit excisions are closed with fine subcuticular sutures and the lateral incision is left open. ⏎

Karydakis flap (lateralisation of midline)

In this procedure, an ellipse of skin and underlying fat down to the deep fascia is excised. The ellipse is parallel to, but 2 cm from, the midline. It must be at least 5 cm in length, as there is increased tension on closure of a short ellipse. The medial side of the incision should just cross the midline and should encompass all of the diseased midline tissue (Figure 15.25a). In extensive natal cleft disease, a long ellipse may be required, but this does not create any problem. However, when there are bilateral sinus extensions, it may not be possible to excise all diseased tissue with this technique. The ellipse must be symmetrical, and the surgeon must resist the temptation to cut the lateral part of the ellipse less generously in an attempt to remove less tissue, as this only results in the scar failing to lie away from the midline. The whole length of the medial side



15.25 Karydakis flap. (a) The long axis of the ellipse is parallel to the midline and 2 cm from it. ~~The length of the~~ ellipse must be such that the medial side of the ellipse crosses the midline to include all diseased midline tissue. The lateral side of the incision must be planned so that the ellipse is symmetrical. (b) An undercutting incision is made along the whole length of the medial side, 1 cm below the skin surface. This undercut should be extended out for 2 cm. (c) The medial flap is unrolled and advanced over the midline. Deep sutures are placed between points X and Y. (d) The final scar is not in the midline. ⏎



15.26 Limberg rhomboid flap. Marking is essential. B–D is 60% of the length of A–C. D–E is a direct continuation of B–D and the same length as A–B. E–F and C–D are parallel and of the same length. The tissue within A–B–C–D is excised. A flap of C–D–E–F is mobilised on a pedicle of C–F. ⏎

of the incision is then mobilised by undercutting a distance of 2 cm at a depth of 1 cm (Figure 15.25b). In thin patients, the undercutting incision may be on the deep fascia. Any strapping to distract the buttocks is now removed. The first sutures are placed between the limit of the undercutting incision and the deep fascia in the midline (Figure 15.25c). These draw the flap over the midline and create a new shallow midline sulcus. Pressure applied by an assistant to unroll the flap as the sutures are tied will reduce tension. A vacuum drain and a second layer of more superficial fat sutures are then inserted, and finally the skin is apposed with interrupted non-absorbable sutures. The wound lies a few centimetres from the midline and the patient has a new shallow natal cleft with healthy unscarred skin (Figure 15.25d).

LIMBERG RHOMBOID FLAP (OBLITERATION OF CLEFT)

The patient is placed prone and the buttocks are strapped apart. A rhomboid area of skin and subcutaneous fat is excised, which includes both the midline pits and any lateral sinus extensions (Figure 15.26). (The long axis of the rhomboid is in the midline and its shape is determined by angles of 60° at A and C and 120° at B and D.) Accuracy is essential, and the tissue to be excised and the flap to be mobilised must be measured and marked at the start of surgery. Planning using precise angles is difficult, and the following linear measurements are an alternative.[19] The line A–C is drawn and its length is measured. C should be adjacent to the perianal skin and A is placed so that all diseased tissue can be included in the excision. The line B–D transects the midpoint of A–C at right angles and is 60% of its length. It is this ratio that determines the correct shape of the rhomboid. The flap is planned so that D–E is a direct continuation of the line B–D and is of equal length to the incision B–A, to which it will be sutured after rotation. E–F is parallel to D–C, and of equal length. After rotation, it will be sutured to A–D.

The skin and subcutaneous fat to be removed are excised down to, but not including, the deep fascia. The flap is raised so that it includes skin, subcutaneous fat and the fascia overlying the gluteus maximus. It is then rotated to cover the midline rhomboid defect, and the defect this creates can be closed in a linear fashion. Deep absorbable sutures, to include fascia and fat, are placed over a vacuum drain and then finally the skin is closed with interrupted sutures. This operation produces a tension-free flap of unscarred skin in the midline.

ENDOSCOPIC PILONIDAL SINUS TREATMENT

This is a minimally invasive approach to pilonidal sinus that is performed using a fistuloscope equipped with a working channel and an irrigation channel. It involves a diagnostic phase in which the tract anatomy is delineated, following which the tract is cleared of hair and debris. Finally, the tracts are cauterised from the inside under direct endoscopic vision. It offers the advantages of less postoperative pain, quicker recovery, quicker wound healing and a good cosmetic result, albeit with a higher risk of recurrence.[20,21]

RECTOVAGINAL AND ANOVAGINAL FISTULAE

Rectovaginal and anovaginal fistulae are communications between the vagina and the rectum or the anal canal, respectively. They have a wide spectrum of aetiology and pathogenesis that needs to be identified and understood before treatment to achieve a successful outcome:

- Obstetric trauma is globally the most common cause of rectovaginal and anovaginal fistulae. The damage may be from direct tissue disruption during extension of the fetal head that results in a perineal tear and anovaginal fistula or ischaemic pressure necrosis induced by the fetal head during a prolonged, obstructed labour that results in a rectovaginal fistula.
- Chronic faecal impaction in older, debilitated patients can cause rectovaginal fistulae either by ischaemic pressure necrosis or due to trauma from the nozzle of an enema device.
- Purely mechanical causes include incorporation of the vagina in the staple line of a coloanal anastomosis.
- Anovaginal fistulae may be secondary to anal crypt gland infections and intersphincteric abscesses.
- Chronic inflammation: fistulae are associated with Crohn's disease and tuberculosis. A late pouch–vaginal fistula is common if an ileoanal pouch has been created in a patient with Crohn's disease and represents ongoing Crohn's inflammation. However, late pouch–vaginal fistulae may occur secondary to simple cryptoglandular sepsis, deep pelvic sepsis or mechanical and ischaemic factors.
- Pelvic sepsis: an anastomotic breakdown of a coloanal or ileal pouch–anal anastomosis may present with a rectovaginal fistula. The initial anastomotic leak results in a pelvic collection, which then discharges into the vagina, or an infected haematoma discharges both into the vagina and into the lumen of the bowel through the anastomosis.
- Malignancy: a locally invasive, primary or recurrent, rectal or gynaecological malignancy may cause a rectovaginal fistula.
- Radionecrosis, as a result of progressive obliterative endarteritis, can result in a fistula that may be difficult to differentiate from tumour recurrence.

These fistulae are less likely to heal spontaneously, as they are short, wide and lined with epithelium, and there is often other pathology such as radiation and chronic inflammation that prevents healing. Lastly, a functional anal sphincter complex forms a high pressure zone distal to the fistula.

SURGERY OF RECTOVAGINAL FISTULAE

A true rectovaginal fistula is extrasphincteric and an anovaginal fistula is either extrasphincteric or trans-sphincteric. Simple laying-open techniques are therefore seldom satisfactory and some form of surgical repair is usually indicated. However, repair is not always possible or is doomed to fail. The surrounding tissue may be either scarred or ischaemic, whether compromised by previous infections, surgery or radiotherapy. There may also be malignant invasion. Anovaginal fistulae associated with Crohn's disease are prone to recur, even after seemingly successful surgery. Long-term loose seton drainage is sometimes of benefit, but has little to offer in a short, wide track with symptoms due to faecal contamination of the vagina. Fibrin glue is also less successful in short, wide fistulae. Not infrequently, a patient with a rectovaginal or anovaginal fistula that cannot be repaired has to decide whether their symptoms are sufficiently severe that they would prefer to have a permanent diversion colostomy.

If repair is to be undertaken, an anal advancement flap, performed in the prone jack-knife position, is suitable for most small anovaginal fistulae. Larger, higher, true rectovaginal fistulae above the sphincters are more easily approached *per vaginum* or from the perineum, with the patient in the lithotomy position. Very high rectovaginal fistulae and colovaginal fistulae are approached from the abdomen. There are several planes between the vaginal and the rectal mucosa that can be entered from the perineum. For all surgery in this area, surgeons must thoroughly understand the planes in which they are working or damage to sphincters is inevitable. An intersphincteric dissection is appropriate for a small low fistula, but it is easier to extend the dissection more proximally for a higher fistula if an extrasphincteric approach is used. The choice of approach depends on access, the size and height of the fistula, the condition of local tissues and often, most importantly, the plane in which the surgeon feels most confident.

POSTPARTUM ANOVAGINAL AND RECTOVAGINAL FISTULAE

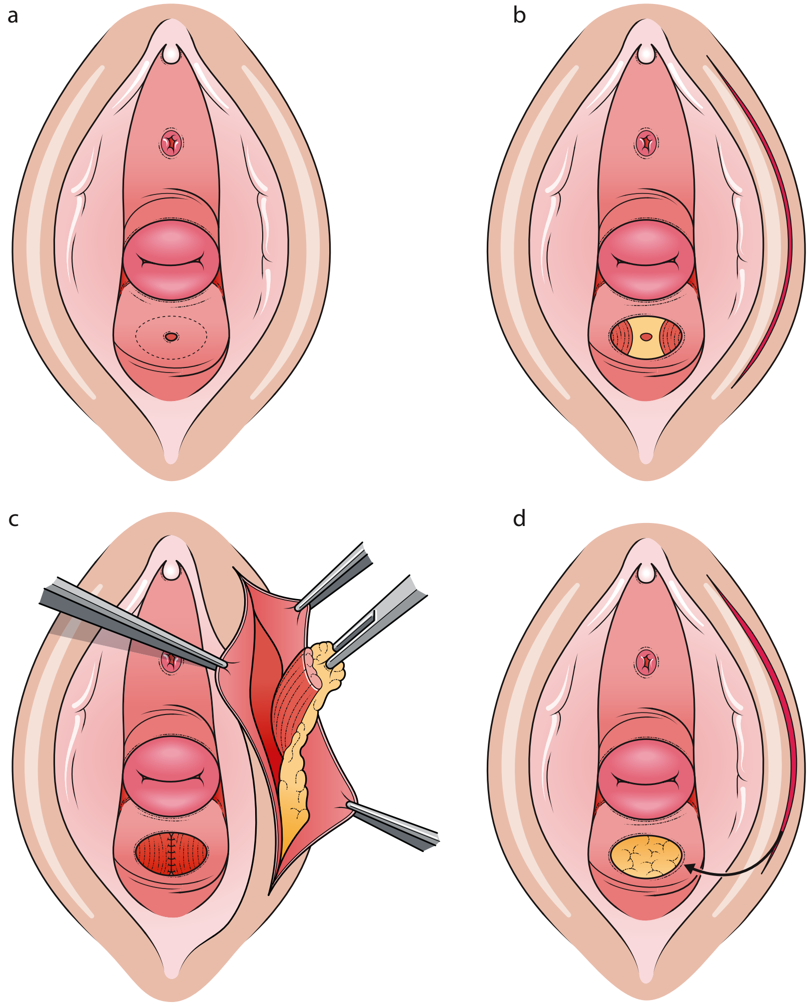
Postpartum anovaginal and rectovaginal fistulae are common in the developing world. They are most commonly associated with prolonged or difficult deliveries, but they fall into three distinct categories:

1. The first category is the result of a fourth-degree perineal tear, wherein the anal sphincters are also disrupted. The emergency sphincter repair (described below) is combined with repair of the anal and vaginal mucosa. The tissue is healthy, and immediate repair has a good chance of success. However, if the deeper aspects of such a repair fail, the patient may be left with healed perineal skin between the anal and vaginal orifices but an anovaginal fistula above, which is usually associated with significant anterior sphincter disruption.
2. The second category is a tear above an intact perineum. The anal sphincters may be damaged or intact, and there may have been no significant perineal skin tear to alert the birth attender to the significant deeper damage. These fistulae are usually diagnosed a few days after delivery at the time of the first bowel movement.
3. The third variety is encountered almost exclusively in areas remote from obstetric intervention. A woman has usually been in labour unsuccessfully for days with a deeply engaged head and pelvic outlet disproportion. Eventually, a stillborn child is delivered but only after ischaemic pressure necrosis has occurred within the maternal pelvis. The most common damage is to the bladder against the pubis, and a vesicovaginal fistula forms (see Chapter 26). In more severe cases, there is additional ischaemic pressure necrosis of the posterior vaginal wall and the anterior rectal wall, and a rectovaginal fistula develops. The perineal skin and anal sphincters are frequently undamaged. Diagnosis may be delayed for a week, or more, as the fistula only becomes apparent as necrotic tissue sloughs.

Repair of these fistulae depends on the time of presentation and whether a sphincter repair is also required. Unless the repair can be performed within 24 hours of delivery, a delay of 2–3 months is advisable and a defunctioning stoma may be required in the interim. A small fistula associated with a disrupted sphincter is best approached from the perineum. A larger, higher fistula is easier to repair *per vaginum*. The edges are excised and then each layer is repaired separately, starting with the rectal mucosa. Extensive dissection above the fistula, and laterally in the plane between the vagina and rectum, increases tissue mobility and enhances the chance of success. The vaginal suture line should be positioned, if possible, so that it lies to one side of the rectal closure. Interposition of tissue between the mucosal suture lines is highly desirable. An anterior levatorplasty will achieve this or, alternatively, a local flap can be used. In injuries following pressure necrosis, tissue loss may be extensive, necessitating an abdominal approach to resect the damaged rectum and allow mobilisation of the colon to form a neorectum.

LOCAL FLAPS

Local flaps provide tissue for interposition in the closure of rectovaginal fistulae. A *Martius flap* (Figure 15.27) consists of the fat pad of a labium majus, with the underlying bulbocavernosa muscle, mobilised on a posterior pedicle containing the perineal branch of the pudendal artery. It is dissected out through a labial incision with the patient in the lithotomy position. The flap is swung through a subcutaneous tunnel to lie over the rectal closure (Figure 15.28). Alternatively, an island of skin with underlying fat, fascia and muscle can be cut from the perineal groin crease. The deep attachment of the flap

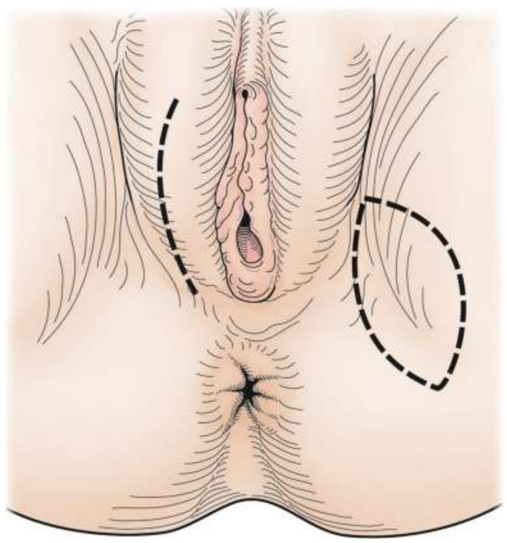


15.27 Martius flap. (a) Mid-level rectovaginal fistula. (b) Elliptical incision to expose defect on the anterior rectal wall. (c) Rectal defect closed; muscle and adipose tissue flap harvested. (d) Flap tunnelled into the rectovaginal space and used to cover the suture line. ⏎

is preserved to maintain blood supply, and it is then tunnelled under the lateral perineal skin and interposed between the anus and vagina (Figure 15.28). An island of skin with underlying fat, fascia and muscle can be cut from the perineal groin crease and used to bridge the vaginal mucosal defect, if the defect is large.

A *gracilis muscle flap* is a commonly used muscle flap in perineal reconstruction. The vascular supply to the gracilis is a branch from the medial circumflex femoral artery and its venae comitantes, and its innervation is a branch of the obturator nerve. The gracilis is detached at its insertion onto the medial tibial condyle, mobilised proximally, preserving its blood supply and innervation, and the flap is brought into the perineum through a subcutaneous tunnel. An island of skin may be transferred along with the muscle if required to bridge a large mucosal defect. Its long and slender anatomical shape, and a consistent neurovascular bundle that usually is unaffected by perineal trauma or pelvic irradiation, make a gracilis flap a very reliable option to reconstruct anovaginal and rectovaginal fistulae.

These techniques are particularly important when there is a large fistula with associated tissue loss from pressure necrosis or when the blood supply to the tissues is poor from previous surgery or radiotherapy. Flap operations will be disappointing in the hands of the occasional operator, and referral to those with a special interest and expertise is recommended.



15.28 Separation of the suture lines is desirable in the repair of vaginal fistulae. Local flaps can be utilised. A Martius flap consists of the bulbocavernosa muscle and fat elevated from the labium majus. The posterior pedicle is retained. This flap reaches with ease for a vesicovaginal fistula repair, but it can also reach for a rectovaginal fistula repair. An alternative flap can be obtained from the perineal groin crease. ⏎

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16 Surgery of the groin

Mark Szymankiewicz, Damian Mayo and Louise Hendra

INGUINAL HERNIAE

Surgery of the groin is dominated by surgery of inguinal herniae, and an understanding of the anatomy and development of the region is essential to the surgeon.

ANATOMY

The *inguinal canal*, which is about 3–5 cm in length, runs obliquely through the muscles, aponeuroses and fasciae of the abdominal wall above the medial part of the inguinal ligament. Its internal and lateral end is the *deep inguinal ring*, an opening in the transversalis fascia, classically described as 1 cm above the midpoint of the inguinal ligament and immediately lateral to the inferior epigastric vessels. Its external and medial end is the *superficial inguinal ring*, a triangular aperture in the aponeurosis of external oblique immediately above the pubic tubercle and the medial end of the inguinal ligament.

Boundaries

The *anterior wall* is formed in its whole length by the aponeurosis of external oblique and in its lateral third by the lowest fibres of internal oblique arising from the inguinal ligament. The *posterior wall* is formed in its whole length by the transversalis fascia and in its medial half by the conjoint tendon. The *roof* is formed by the lower borders of internal oblique and transversus abdominis, which arch over the canal before fusing to form the conjoint tendon. The *floor* is the grooved upper surface of the inguinal ligament and its reflection onto the superior ramus of the pubis – the lacunar ligament.

Contents

In males, the main content of the canal is the *spermatic cord* and, in females, it is the *round ligament*. The *ilioinguinal nerve* lies in the medial part of the canal and either emerges through the superficial ring or pierces the aponeurosis close to it. The *spermatic cord* consists of the vas deferens, with its accompanying small artery, the testicular artery, and the pampiniform plexus of veins, lymph vessels and autonomic nerves. Whilst difficult to distinguish clinically, the cord has three *coverings* (each derived from its respective layer of the abdominal wall):

1. The internal spermatic fascia derived from the transversalis fascia at the deep ring
2. The cremasteric muscle and fascia derived from internal oblique
3. The external spermatic fascia derived from the external oblique aponeurosis at the superficial ring

DEVELOPMENT

The testis develops as a retroperitoneal, intra-abdominal organ that normally migrates into the scrotum during the last trimester of intrauterine life. Immediately prior to its entry into the deep ring, the testis and the testicular vessels lie intraperitoneally. Migration down the canal and into the scrotum is guided by the gubernaculum and is associated with an out-pouching of peritoneum, the *processus vaginalis*. An undescended (cryptorchidism) or ectopic testis is the result of a failure of full testicular descent and is thus often associated with a paediatric indirect inguinal hernia. The fully descended testis projects into the distal part of the processus vaginalis, which forms the tunica vaginalis of the testis. The rest of the processus is usually obliterated. A wide persistent peritoneal tube is an indirect inguinal hernia sac extending into the scrotum. A patent peritoneal tube that is too narrow to allow herniation is described as a *persistent processus vaginalis*, which can be very subtle. It maintains the communication between the space around the testis and the peritoneal cavity, and an infantile hydrocoele of trapped peritoneal fluid forms. Obliteration of the processus may fail only in the proximal segment of the

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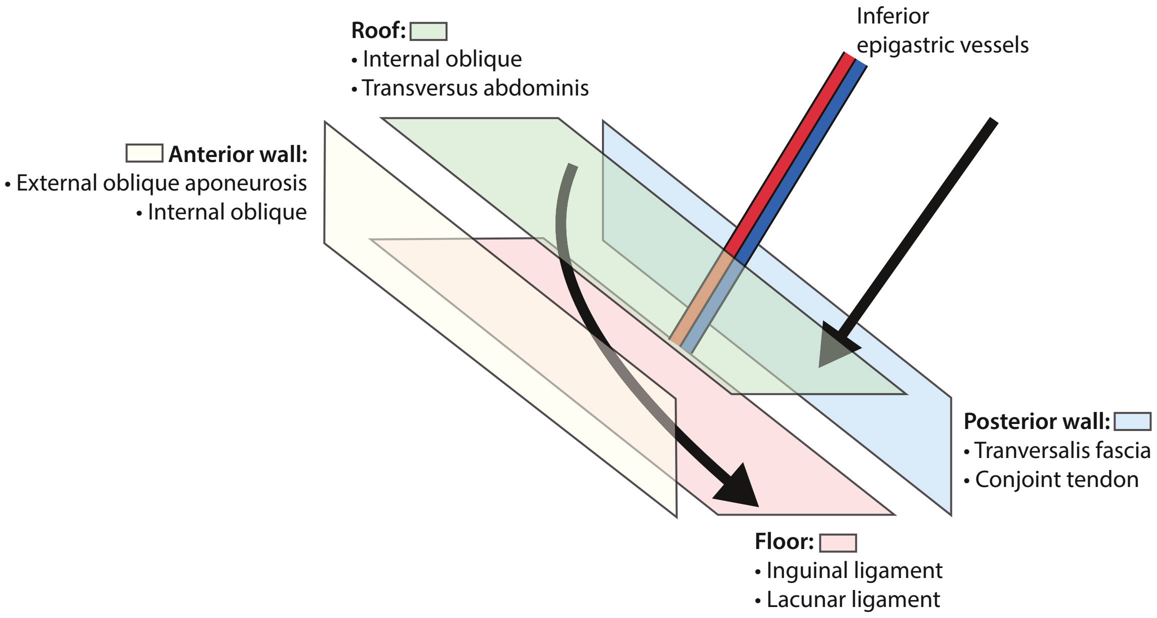


16.1 Schematic illustration of a right-sided inguinal canal. An indirect inguinal hernial sac traverses the oblique lie of the inguinal canal, which it enters through the deep ring lateral to the inferior epigastric vessels. It lies within the coverings of the cord anterior to the vas and vessels. A direct inguinal hernia enters the inguinal canal through a posterior wall defect medial to the inferior epigastric vessels. It lies behind the cord and its coverings. ⏎

peritoneal extension. A short, wide persistent peritoneal tube then forms an indirect inguinal hernial sac confined to the groin, and a narrow tube may result in an *infantile hydrocoele of the cord*.

The inguinal canal in infancy and early childhood is proportionally shorter and less oblique than in the adult, with the deep and superficial inguinal rings overlapping each other. The testis is commonly retractile in childhood, and may be withdrawn intermittently into the inguinal canal or even into the abdomen by cremasteric muscle contraction. A high riding or retractile testis in infants may be associated with an ipsilateral hernia.

Indirect inguinal herniae

In such a hernia, the *sac*, or peritoneal tube through which the abdominal contents protrude, accompanies the spermatic cord in its oblique course through the inguinal canal. The neck of the sac, which is often constricted, lies at the deep inguinal ring, lateral to the inferior epigastric vessels (Figure 16.1). The sac is enclosed within the coverings of the cord and lies anterior to the vas and testicular vessels. Some of these herniae may be congenital in origin, but remain covert with an empty sac for many years and present in adult life. A sliding indirect hernia is a term used to describe a situation when a variable portion of the herniated tissue is extraperitoneal (see Chapter 6).

Direct inguinal herniae

A direct inguinal hernia traverses only the medial part of the inguinal canal and therefore does not pursue the oblique course taken by the spermatic cord. It protrudes from the abdominal cavity through the posterior wall of the inguinal canal medial to the inferior epigastric vessels (Figure 16.1). These herniae seldom descend completely into the scrotum.

The sac may be narrow-necked and protrude through a small posterior wall defect. More often, it is wider at its neck than at its fundus, and is little more than a bulging of the peritoneum as it protrudes through a wide defect. The hernia lies behind the spermatic cord and is covered by a thin, stretched fascial layer derived from the edges of the defect.

Pantaloon herniae

Occasionally, an inguinal hernia is a combination of both a direct and an indirect sac. The epigastric vessels may be distorted, but will often create a 'crotch' and thus the hernia resembles a pair of trousers (pantaloon). It is also sometimes described as a saddlebag hernia.

Selection for surgery

Treatment of inguinal herniae should be advised for all herniae that carry a significant risk of strangulation. Herniae that are difficult to reduce, and all herniae in infancy, are in this category.

Wide-necked direct herniae, which reduce spontaneously immediately on lying down, are very unlikely to strangulate. Many of these herniae are asymptomatic and, if the patient is older and an operation would entail a significant risk, there may be little justification for surgery. Repair is, however, recommended for the majority of herniae in younger people, because even if they are asymptomatic and unlikely to strangulate, the natural history is for them to increase in size, becoming problematic later. Recommendations for repairing asymptomatic inguinal hernia vary between organisations. The general advice is balanced between surgery and watchful waiting. Most recommend surgery if the patient wants it, is young and active or likely to develop symptoms due to lifestyle or profession.[1] The major international hernia societies all agree that watchful waiting is reasonable for asymptomatic or minimally symptomatic hernia, as the risk of complications in asymptomatic herniae is small.[1,2] The risk of complications such as chronic pain must be made clear when operating on an asymptomatic or minimally symptomatic hernia.

Incarcerated (irreducible) herniae should always be considered for repair unless the risks of surgery preclude this. Certainly, any hernia that has only recently become irreducible is at high risk of progression to strangulation. Some long-standing but uncomplicated irreducible herniae may be left alone if not symptomatic.

Herniotomy Herniotomy involves simple ligation and division of the neck of the sac. It is the correct procedure for the congenital indirect herniae encountered in infancy, childhood and adolescence. Whilst in young children the deep and superficial rings almost line up, in older children incision of the anterior wall of the inguinal canal (the external oblique aponeurosis) may be required to ensure adequate access to the true neck of the sac. This is especially true if a concurrent hernia and orchidopexy is being performed.[3]

In young adults, some surgeons advocate that a herniotomy may be all that is required for an indirect hernia due to the likely congenital origin, as long as good inguinal canal musculature is maintained. Most surgeons, however, favour some form of posterior wall repair, even in young adults, and all would agree that the risk of recurrence after simple herniotomy is unacceptably high in middle-aged and older people. A recurrent inguinal hernia is almost always a direct hernia regardless of whether the initial hernia was direct or indirect. Although the deep inguinal ring remains a point of potential weakness, as it cannot be closed unless the testis is removed, a recurrent indirect hernia is rare.

Herniorrhaphy Herniorrhaphy implies some form of repair or reinforcement of the posterior wall of the inguinal canal. The repair in women is essentially identical to that in men except that the round ligament can be sacrificed and the deep ring closed. The posterior wall of the inguinal canal can be approached through the canal, and this is the most common route for open repair. An open preperitoneal approach from above the inguinal canal is preferred by some surgeons for bilateral repairs and for recurrences. This is also the approach used in the minimal-access extraperitoneal repair described below.

A great number of methods of repair of the inguinal canal have been employed over the past 130 years, with hernia recurrence appearing to be related more to the individual surgeon than to the method of repair employed. However, the *Shouldice repair* was generally regarded as the gold standard of open herniorrhaphy for many years, although it is difficult to perform well and results were very variable. More recently, large multi-centre trials have established that the most secure method, independent of surgeon bias, is the tension-free mesh repair popularised by Lichtenstein. Whilst this has become the gold-standard approach in most high-income countries for several decades now, suture techniques still predominate in resource-limited settings due to the cost of commercial mesh. However, several innovative approaches using generic 'mosquito net' mesh (low-cost mesh specifically designed for this setting, with the same properties as commercial polypropylene mesh, and manufactured in large sheets resembling a mosquito net) have enabled mesh surgery services to be established and flourish in a resource-limited setting.[4]

Laparoscopic hernia repair has steadily gained popularity, especially for bilateral and recurrent herniae.[5] In expert hands, the complications and recurrence rates are comparable to rates with standard open groin repairs, and postoperative recovery is faster.[6] Additionally, the incidence of chronic groin pain is reduced.[7,8] Disadvantages include the need for general anaesthesia, access to laparoscopic equipment, suitable training and increased costs. Case selection is important, and very large herniae may not be adequately treated with such techniques. The *transabdominal preperitoneal* (TAPP) procedure is generally considered the easier technique to master. The *totally extraperitoneal* (TEP) procedure was initially believed to be superior, but recent comparisons have not confirmed the increased complications and recurrences reported in the early TAPP results.[9] Both techniques have their advocates and are currently considered comparable if done properly.

Emergency inguinal hernia repair

Emergency repair is necessary when strangulation is present or imminent. The first priority is release of the strangulated contents and resection if the contents are infarcted (see Chapter 13 and Figure 13.10). The hernia is then repaired by one of the methods described below. In the presence of strangulated bowel, the operating field is inevitably contaminated with bacteria and it is generally felt that mesh is better avoided in these circumstances.

Recurrent inguinal hernia repair

The dissection in the inguinal canal may be straightforward but may be very difficult because of the presence of dense scar tissue. Occasionally, the cord is lying very superficially and can be damaged even before this stage is reached. Cord damage is much more likely in a recurrent hernia repair and the possible need for an orchidectomy, or late loss of the testis, should be discussed with the patient preoperatively. The preperitoneal approach – either open or laparoscopic – should be considered, as it avoids the scarring within the inguinal canal. Increasingly, though, if the original repair has been performed laparoscopically in the preperitoneal plane, it may be preferable to perform the second operation through the inguinal canal via an open approach.

A recurrent hernia occasionally occurs through the prevascular space in front of the femoral artery and vein. Safe dissection may require division of the medial end of the inguinal ligament. The inguinal ligament is reattached after the sac has been dissected off the vessels and the peritoneum closed.

OPEN ADULT INGUINAL HERNIOTOMY

Open adult inguinal herniotomy is usually identical to the first stage of a herniorrhaphy. General, regional or local infiltrative anaesthesia is suitable.

The classic incision is made 2.5 cm above, and parallel to, the medial three-fifths of the inguinal ligament, but a more horizontally placed skin crease incision will produce a more acceptable scar. One or more superficial epigastric veins cross the line of incision in the subcutaneous fat and require ligation or diathermy coagulation. The incision is deepened until the aponeurosis of external oblique is exposed. The superficial inguinal ring, through which the cord emerges, is identified. The external oblique aponeurosis is divided in line with its fibres, the incision being placed so that it opens into the upper part of the superficial ring (Figure 16.2a). Forceps are applied to the two cut edges and both leaves elevated. The ilioinguinal nerve can usually be identified and preserved. However, if the nerve is going to be tangled up in the placement of mesh, there is increasing consensus that sacrificing the ilioinguinal high up should be considered. This decision is a balance between the invariable numbness that will occur versus the risk of potentially debilitating and difficult-to-treat chronic pain.

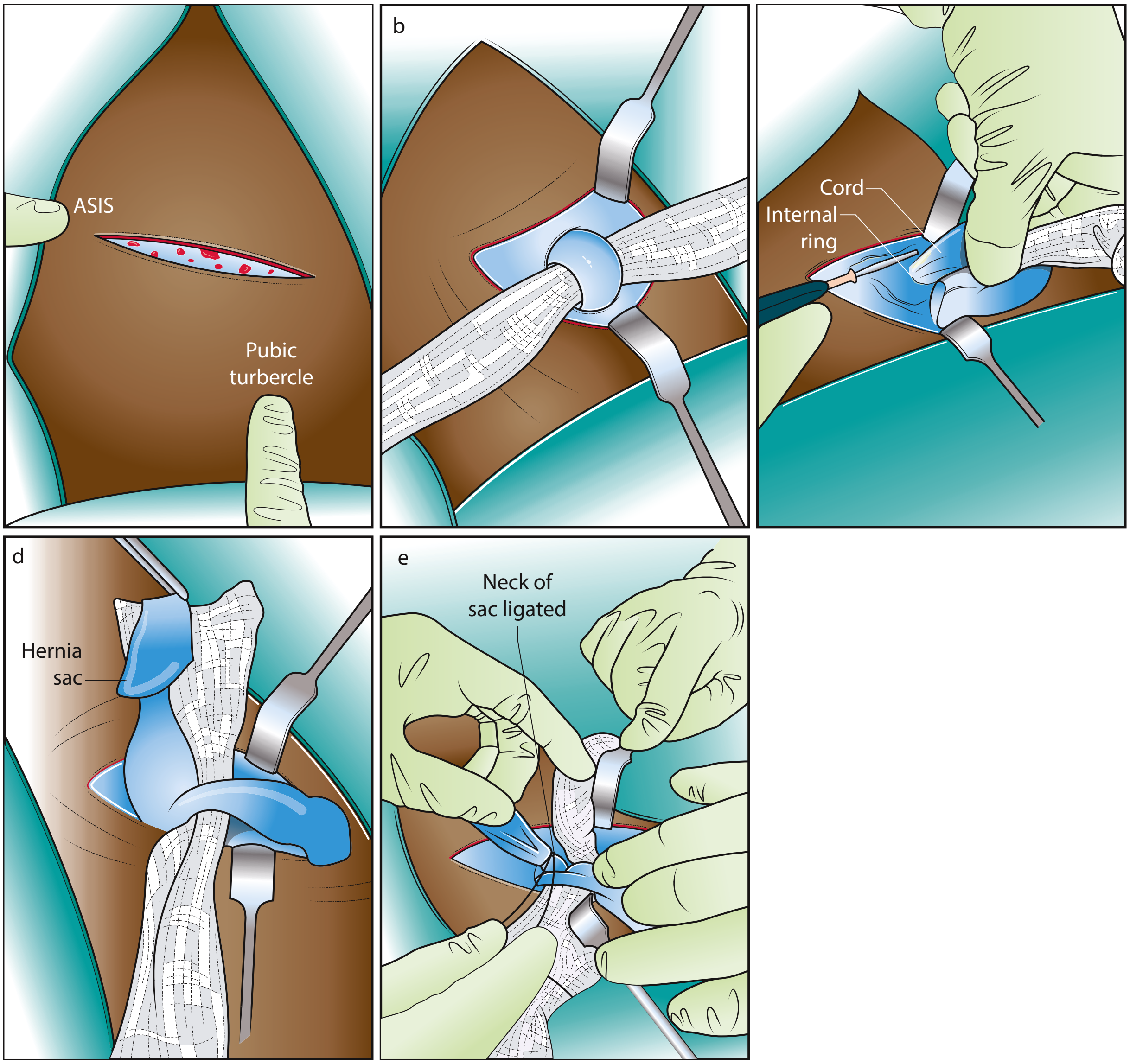
The cord, with its coverings, is lifted up from the medial part of the incision and spread out on the surgeon's finger (Figure 16.2b). The coverings are incised longitudinally and separated off the underlying cord. The sac appears as a pearly white structure, lying anterior to the main components of the cord. It is most easily identified at the fundus, the crescentic border of which lies transversely across the cord, and is picked up and held in artery forceps (Figure 16.2c). The cord must also be inspected in this way when a direct hernia is repaired, as an additional indirect sac is not infrequently present. The cord structures are then separated from the sac as far as the neck. Sharp dissection with scissors or diathermy, and blunt stripping with a swab, are acceptable techniques. Care must be taken in all methods to avoid injury to the testicular vessels. The vas is also vulnerable to inadvertent division, as it often lies separate from the other cord structures, closely applied to the sac. A pair of Lane forceps, silastic catheter or a swab around the cord structures are useful both to safeguard them and to provide counter-traction (Figure 16.2d). Dissection continues until the neck of the sac is exposed.

The sac should then be opened, some distance from the neck, to ensure that it is empty. A finger inside the sac can also be used to feel for an excessively thick medial or lateral wall, which could represent an additional sliding component to the hernia. Tension on the sac then allows a transfixion suture to be placed immediately above the neck (Figure 16.2e). Care must be taken to ensure that the underlying bowel is not transfixed. The sac is then amputated 1 cm distal to the ligature and, if the dissection has been adequate, it will retract inside the deep ring. If no repair is deemed necessary, the external oblique is closed and the skin is sutured.

The alternative approach to the cord for a simple herniotomy is through an incision in the external oblique, which leaves the superficial ring intact. Access is more limited, but the advantage is less disturbance to the anatomy and function of the inguinal canal. This approach is particularly favoured by paediatric surgeons and is described below.

Scrotal hernia

In a scrotal hernia, where there is often dense scar tissue and the fundus of the sac may not come easily into view, it is considered reasonable to transect the sac leaving the distal part of the sac *in situ*. The sac is separated for a short distance from the cord structures and is then divided transversely. The distal part



16.2 Adult right herniotomy. (a) A transverse skin crease incision is made and dissection is continued down to the external oblique aponeurosis, which is divided. (b) The cord with its coverings is delivered up into the medial part of the incision. (c) The cord's coverings are divided longitudinally and separated off from the cord. (d) The cord is separated from the sac as far as the neck. (e) After opening the sac to check that it is empty, the sac is transfixed just above its neck. ASIS, anterior superior iliac spine. ⏎

is dropped back, whilst the proximal part is cleared up to its neck and removed in the usual fashion. This method obviates the dissection required to deliver the sac from the depths of the scrotum and greatly reduces the risk of postoperative haematoma.

Sliding hernia

A sliding hernia contains tissue that lies outside the peritoneal sac. This may be extraperitoneal fat, sigmoid colon, caecum or bladder. If the associated sac is small and the situation is fairly obvious, there is no necessity to excise the sac and the abdominal contents are merely replaced before repair of the hernial defect. On other occasions, the bowel or bladder forms one wall at the neck of a large sac and is in danger of injury if not recognised. Only a partial sac excision is then possible, the remaining extraperitoneal tissue being simply replaced into the abdominal cavity before the posterior wall repair. However, it is sometimes possible to release colon adherent to one side of the neck from within the sac. It can then be replaced within the peritoneal cavity and the sac transfixed at its neck.

Direct hernia

A direct inguinal hernia seldom requires a herniotomy, as the herniated tissue is often only extraperitoneal fat or bladder without a peritoneal sac. Any peritoneal sac that is present is usually only a wide-necked bulge, which can be left unopened. The method of closure of the posterior wall defect in the inguinal canal is dictated by the type of repair to be undertaken.

INGUINAL HERNIORRHAPHY AND HERNIOPLASTY

Surgery to repair an inguinal hernia through the inguinal canal commences like the herniotomy operation described above followed by one of the techniques described below.

Mesh repair

The use of a mesh to reinforce the hernia repair is termed a hernioplasty. This is in comparison to a herniorrhaphy, where only a tissue repair is performed. A mesh repair is simple to perform and the recurrence rates are low. The use of mesh is recommended for all adult groin hernia repairs by the major hernia societies.[1] A sheet of mesh is used to support the whole posterior wall of the canal. Mesh plugs are used by some surgeons to occlude small direct defects or narrow a stretched deep ring. Mesh repairs are tension free and result in less early postoperative pain than other open repairs. Mesh infection, which occurs in around 1% of patients, is a serious complication, which usually requires the mesh to be removed. Routine antibiotic prophylaxis is generally recommended (see Chapter 3). As discussed above, the cost of mesh may be prohibitive for surgeons working within many resource-limited healthcare environments, but innovative approaches using generic 'mosquito net' mesh have a growing body of supporting evidence.[10]

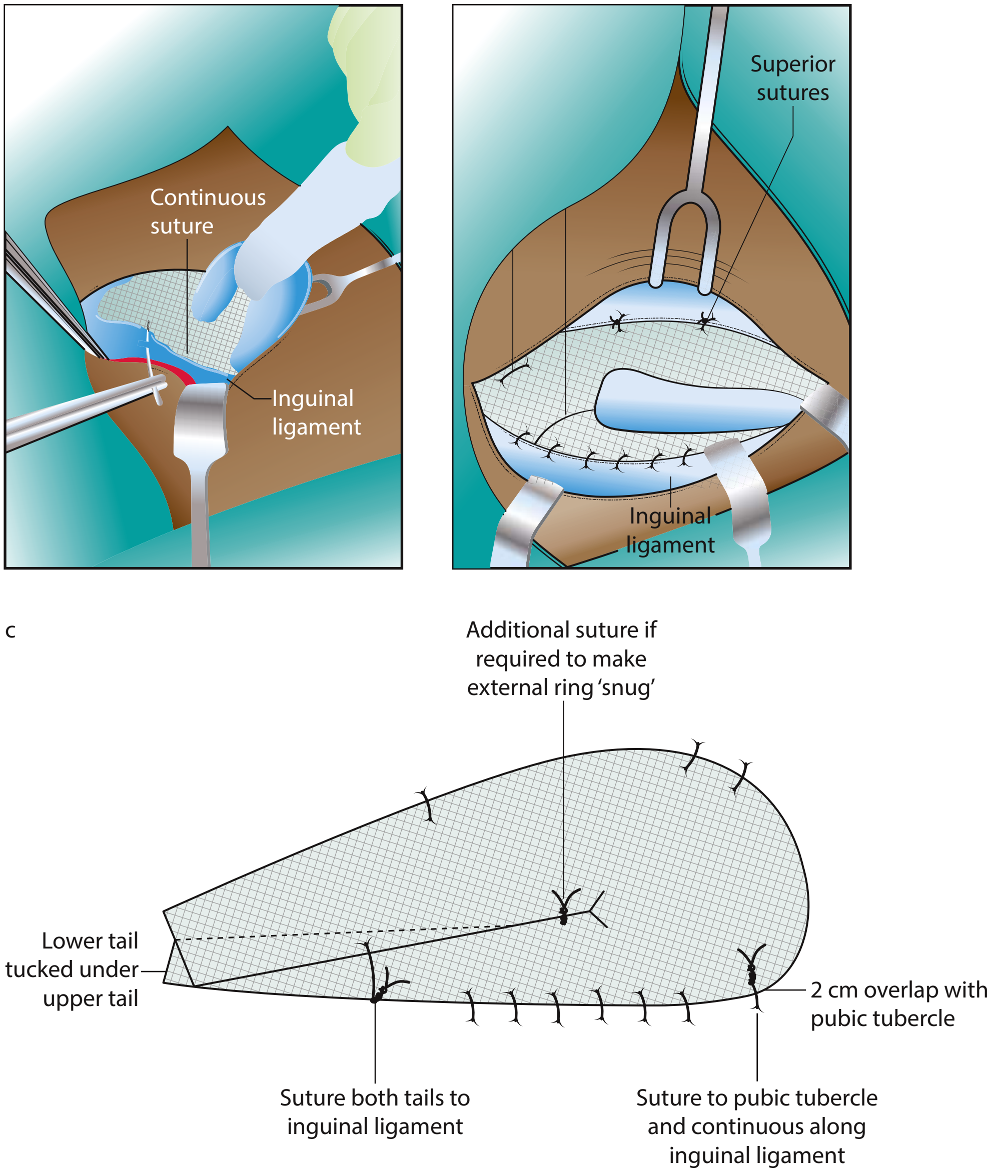
Surgical technique An indirect herniotomy is completed. A direct sac does not usually need to be excised or opened and, as the mesh will support the whole posterior wall of the inguinal canal, a formal repair of the fascial defect of a direct hernia is considered unnecessary by many surgeons. Others prefer to make a circumferential incision through the stretched fascia at the edge of the defect and close it with a continuous suture. An absorbable suture is satisfactory, as it will be supported ultimately by the mesh. This step certainly makes placement of the mesh easier if the hernia is large, but may increase postoperative pain; it certainly should be avoided if the defect is wide and tension would ensue from this suture. The whole posterior wall of the inguinal canal must then be exposed. Cremasteric muscle fibres running from the deep ring to the cord are divided, and cremasteric vessels lying along the floor of the canal are ligated and divided. The genital branch of the genitofemoral nerve runs alongside the cremasteric vessels, and surgical opinion varies as to the advisability of preserving or dividing this. The ilioinguinal nerve is vulnerable in all repairs and, if caught up in the sutures, late pain may be problematic. The nerve can usually be safeguarded, but complete division may be considered.[11] A polypropylene mesh is cut to cover the whole posterior wall of the canal and extend around the deep ring. There is no tension, and sutures are only used to prevent early displacement before tissue ingrowth secures it in position. A Prolene™ running suture holds the lower edge of the mesh to the inguinal ligament. An additional series of interrupted 'tacking' sutures along the superior portion of the mesh will prevent displacement of the edges. The cut edges of the 'tails' of the mesh are brought together again around the cord at the deep ring (Figure 16.3) and secured together with Prolene. Sutures should not be placed through the periosteum of the pubic tubercle, as this can be a cause of late groin pain. Care should also be taken not to inadvertently catch the ilioinguinal nerve.

Bassini repair

The original repair developed by Bassini during the 1880s emphasised the importance of the reconstitution of the transversalis fascial layer of the posterior wall of the inguinal canal. However, the modified operations that bore his name had a high recurrence rate.[12,13] Often, the repair was performed too superficially and failed to repair the transversalis fascia, the sutures merely apposing the muscle fibres of internal oblique to the inguinal ligament. Tension was recognised as a potential problem when a true transversalis fascia repair was performed. Vertical release of the anterior rectus sheath, the *Tanner slide*, was a useful later modification, which reduced tension on the repair.

Shouldice repair

This refinement of Bassini's posterior wall repair can offer recurrence rates of under 1% in expert hands.[14] The European Hernia Society guidelines of 2009 state that this is the best non-mesh inguinal hernia repair method.[1] The cremasteric muscle is cleared off the posterior wall, which is then divided throughout its length before reconstitution with a four-layer overlapping technique. The preperitoneal fat is displaced posteriorly and the first layer of the repair is commenced medially, approximating the lower cut edge of the transversalis fascia to the deep surface of the fascia of the upper flap. When the internal ring


Continuous suture
Inguinal ligament
Superior sutures
Inguinal ligament
c
Additional suture if required to make external ring 'snug'
Lower tail tucked under upper tail
2 cm overlap with pubic tubercle
Suture both tails to inguinal ligament
Suture to pubic tubercle and continuous along inguinal ligament

16.3 A right-sided mesh hernioplasty. The mesh is cut to the shape of the posterior wall. It should extend medially beyond the pubic tubercle and laterally beyond the deep ring. A continuous suture attaches the mesh to the inguinal ligament. A few additional sutures prevent rolling up of the edges. Note the slit to allow the mesh to be laid around the deep ring. ⏎

is reached, the last stitch incorporates the stump of the cremasteric muscle to form a new snug internal ring. Suturing is then reversed and the second layer unites the upper cut edge of the transversalis fascia to the inguinal ligament. The third layer approximates the internal oblique muscle to the deep surface of the lower flap of external oblique, close to the inguinal ligament. The final, fourth, layer approximates further muscle, again to external oblique, a portion of which is now incorporated into the posterior wall. It is therefore important that the initial incision in external oblique is not placed too low or its final closure, superficial to the cord, will prove problematic.

It is a difficult repair to perform well, and simpler modifications, in which the third and fourth layers are omitted, have not consistently been associated with these low recurrence rates; by contrast, much higher rates are more generally noted.

Nylon darn repair

After the posterior wall has been cleared and any direct defect closed, an alternative to a mesh is a reinforcement of the posterior wall with a monofilament nylon darn. The darn should be loosely laid in the muscle and must not draw the tissue together. It must cover the whole posterior wall, and no significant gaps should be left between fibres otherwise small narrow-necked direct herniae may occur between strands of the darn. Recurrence rates overall are high except for those performed by surgeons whose darns are so dense that they resemble a mesh. The technique has been generally abandoned in favour of mesh repairs.

Overview

All of the above repairs are suitable for either a general or a local anaesthetic technique. Eric Farquharson's interest in ambulatory hernia surgery was revolutionary at a time when patients were confined to bed for between 2 and 4 weeks after hernia repair.[15] Same-day discharge during the 1950s was only practical after techniques performed under local anaesthesia, but it is now equally appropriate after general anaesthesia.

HERNIA REPAIR UNDER LOCAL ANAESTHESIA

Although always an option, a repair under local anaesthesia is particularly well tolerated in older people and avoids the risks associated with a general anaesthetic. Diathermy and blunt dissection are more likely to cause pain than sharp scissor dissection, and care should be taken to avoid traction on the cord or peritoneum, which can provoke bradycardia and arrhythmias. The incision should always be of adequate length to avoid excessive retraction, and gentleness is essential.

One of the many satisfactory techniques is to inject 5–10 mL of 0.5% lignocaine with adrenaline (prepared by diluting the standard 1% solution with equal volumes of normal saline) immediately under the intended skin incision, and a further 5 mL into the deeper subcutaneous fat at the lateral end. Anaesthesia occurs almost immediately. The skin incision is made, but only at the lateral end is it deepened to the external oblique, where a further 5 mL of the local anaesthetic solution is injected just deep to the aponeurosis. This ensures that the local anaesthetic is in the correct tissue plane and avoids the reported unintentional femoral nerve block. The rest of the wound is then extended down to external oblique. Small nerves run alongside the veins, which have to be ligated in the subcutaneous fat, and before clamping these a further 1 mL of local anaesthetic may be required. The external oblique is then opened and the operation continued in the normal manner. The peritoneum is sensitive, and a few millilitres of anaesthetic should be injected at the neck of the sac before transfixion. Further local anaesthesia is also often required around the cremasteric vessels. Bupivacaine can be mixed with lignocaine for postoperative pain relief or injected separately towards the end of the operation. When bupivacaine is used on its own, the delay in anaesthetic effect has disadvantages.

Bupivacaine injected during surgery under general anaesthesia provides excellent postoperative analgesia for the ambulatory patient. Effectiveness is improved by injecting the bupivacaine at the start rather than after completion of surgery.

Another alternative to general anaesthetic frequently employed in low-resource settings is spinal anaesthesia. This usually results in excellent anaesthesia of the surgical field for approximately 1 hour, with minimal complications if carried out correctly.

PREPERITONEAL INGUINAL HERNIA REPAIR

The preperitoneal approach is particularly useful for bilateral herniae, when a double incision can thus be avoided, and for a recurrent hernia after a groin repair where it avoids the necessity of dissection within a scarred inguinal canal. The sac is approached at its neck, where it is ligated and divided. The remainder of the sac can be left *in situ* if it does not deliver easily. A fascial defect can be satisfactorily repaired from within, but this is not always necessary, as any mesh will be in the ideal position between the peritoneum and the muscle wall, against which it is held by intra-abdominal pressure. Depending on surgeon preference, sutures or staples are often still employed to prevent rolling or displacement of the mesh in the immediate postoperative period. However, increasingly, suture-/staple-free repairs are being adopted and potentially carry an even lower incidence of chronic pain. Preperitoneal repairs are now more commonly carried out laparoscopically.

Open approach

A transverse incision is made two finger breadths above the pubic tubercle and deepened through the anterior rectus sheath. The rectus muscle is then retracted laterally to expose the inferior epigastric vessels, which are ligated and divided. After division of these vessels, it is possible to enter the correct plane on the peritoneum and sweep this off the abdominal wall to deliver the tongue of peritoneum that is entering the hernial orifice. The hernial sac is ligated at its neck, and the mesh is then laid across the defect. It can be easily tethered anteriorly before the peritoneum is allowed to return to its normal position supporting the mesh against the undersurface of the abdominal wall.

Laparoscopic totally extraperitoneal procedure

The laparoscopic TEP repair commences with obtaining preperitoneal access and creating a space within which to work (see Chapter 6). The anatomy is defined and the immediately visible inferior epigastric vessels are a useful landmark. They are vulnerable during dissection, and injury has also occurred to external iliac vessels. The surgeon then works along the roof of the dissection space, either using a balloon dissector or instruments, freeing the peritoneum and preperitoneal fat from the abdominal wall fascia.[16] A direct hernia will separate off the abdominal wall, leaving an area that bulges with gas insufflation. The surgeon starts at the level of the pubic symphysis and works along the iliopubic tract to make a space. Dissection then proceeds laterally, with the inferior epigastric vessels elevated against the abdominal wall for protection. At the deep ring, either the spermatic cord or an indirect sac comes into view. Dissection around the sac allows a wide-necked sac to be inverted, but a narrow scrotal sac can simply be divided. Lateral dissection continues to the anterior superior iliac spine to give adequate space for a mesh to be placed. This dissection can be repeated through the same space to perform a contralateral hernia repair at the same time. The mesh is delivered and unrolled so that it covers both the inguinal and the femoral canals. Increasingly, surgeons are not routinely placing any securing device to hold the mesh. It is more common to secure the mesh with sutures, staples, tacks or glue if performing a bilateral repair or if there is a large direct defect.

Laparoscopic transabdominal preperitoneal procedure

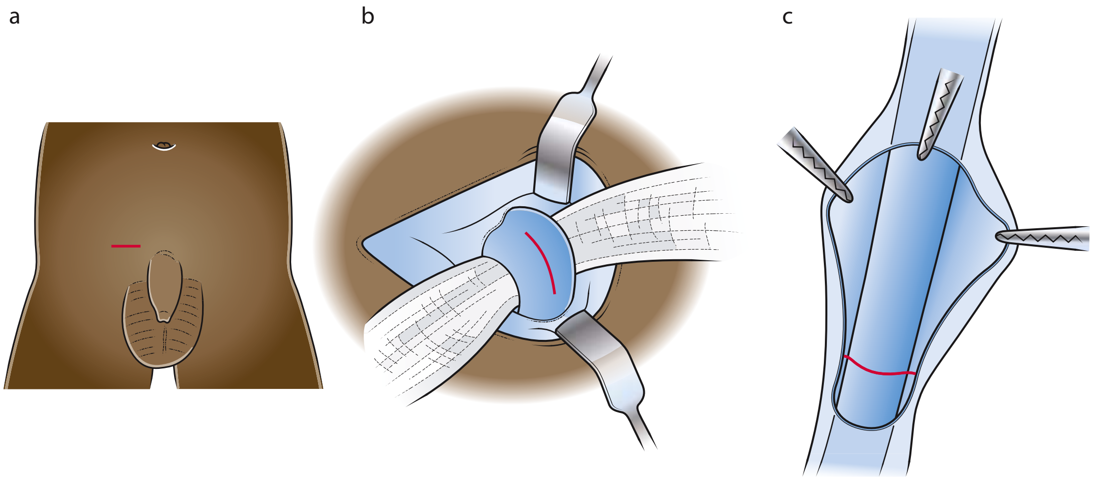
With the laparoscopic TAPP repair, pneumoperitoneum is established with an umbilical camera port and a port in each flank. The peritoneum is then incised in a horizontal line from the anterior superior iliac spine, passing a few centimetres above the neck of the hernia, as far as the medial umbilical ligament. A flap is then raised heading posteriorly from this incision and taking care to lift only a thin layer of peritoneum. This dissection is continued to either side of the hernia neck, and the sac itself is then dissected free from the cord structures and drawn out of the inguinal canal. The vas deferens and gonadal vessels pass posteriorly from the deep ring, and the iliac vessels lie between them. All are potentially vulnerable during dissection and mesh placement.

The mesh is rolled up and introduced through a laparoscopic port, placed in the same position as described in the TEP repair and held in position with staples or sutures. The peritoneal flap is then fixed back in its original position, with either staples or sutures, in order to cover the mesh.

INGUINAL HERNIOTOMY IN A CHILD

Surgery of infantile herniae should not be delayed, as the risk of incarceration and subsequent strangulation is high. Neonates should be operated on prior to leaving the maternity unit, as the risk of strangulation in this cohort is up to 31%.[17] Children under 6 months should be put on the next available appropriate operating list, as the risk is lower than that in neonates but still around 16%.[17] Initial presentation may be with a strangulated hernia. In infants and children, an inguinal herniotomy is sufficient and no repair is necessary. The herniotomy can be performed as described above for an adult hernia, but as no repair is to be performed, there is an argument for disturbing the shutter mechanism of the inguinal canal as little as possible and preserving an unscarred superficial ring. Three approaches to the neck of an indirect sac, which do not divide the superficial inguinal ring, are described below. Although practice and opinion amongst paediatric surgeons is still divided, laparoscopic herniotomy in infancy has gained more acceptance in recent years, with both open and laparoscopic approaches now regarded as safe procedures with equivalent recurrence rates. The laparoscopic approach enables assessment of the patency of the contralateral processus vaginalis and, in emergency cases, avoids operating through oedematous planes. It also has a role in recurrent inguinal herniae, when re-exploration through the scar tissue in the groin can be avoided. Repair is performed using a laparoscopic purse-string suture to close the patent processus vaginalis. This procedure should be performed only by those appropriately trained in laparoscopy in infants, with the correct equipment and instruments, and with appropriate anaesthetic support.

Hydrocoeles are common in infancy and many resolve by spontaneous obliteration of the processus vaginalis. Surgery is therefore normally postponed until the child is at least 2 years old.[18] Encysted hydrocoeles of the cord are less common and seldom resolve spontaneously. The operation for an infantile



16.4 A right infantile herniotomy. (a) A transverse incision above the pubic tubercle. (b) The cord and coverings are identified outside the superficial ring and delivered up into the wound. The coverings are incised and lifted off the cord structures. (c) A thin, wide-necked sac may have to be dissected from within. The vas and vessels are visible through the undivided segment of sac, which must be separated from them very gently as the remainder of the circumference of the sac is divided along the red line. ⏎

hydrocoele is ligation and division of the proximal end of the processus vaginalis, and is thus essentially the same operation as that for an infantile hernia.

The low operation

In this procedure, the cord is approached outside the superficial ring. Although this technique can be applied to all ages, it is most suitable in infants younger than 1 year who have a very short canal and there is overlapping of the superficial and deep inguinal rings. A skin crease incision 2–3 cm in length is made just above the pubic tubercle (Figure 16.4a). The incision is deepened through the membranous layer of superficial fascia, which is a significant layer at this age and may cause confusion if it is mistaken for the external oblique. Veins in the fat can be safely coagulated. Once the external oblique aponeurosis is defined, the lower edge of the wound is retracted and the cord identified just outside the superficial ring. If difficulty is encountered, traction and release of the testis will usually help to identify the cord moving in the fat. The cord is then gently delivered into the wound along with its coverings. A pair of artery forceps passed beneath the cord will hold it securely on the surface under light traction. Alternatively, a vascular sling can be passed under the cord, as shown in Figure 16.4b. The coverings are incised longitudinally. These include the cremaster muscle, which is frequently thick and hypertrophied in association with an infantile hernia. Artery forceps are placed on both cut edges and act as retractors to enable the surgeon to enlarge this incision in the correct plane and to separate the cord from its coverings. It is then possible to lift the cord free, being careful never to grasp the cord structures, and pass another pair of artery forceps under the isolated cord and allow the coverings of the cord to fall back into the wound. It is important to have haemostasis assured before allowing this tissue to retract.

The sac is then identified. A short sac is lifted in its entirety off the vas and vessels. A long scrotal sac is separated from the vas and vessels sufficiently to allow transection. The distal sac is left *in situ* and the dissection restricted to the proximal portion of the sac. Isolation of an *infantile hernial sac* may be extremely difficult, as it is often wide and gossamer thin, with the cord structures spread over the surface. Delicate unhurried dissection with fine instruments and good light is essential. Ideally, the cord structures are teased off the unopened sac, which can be held between finger and thumb. However, this is not always possible and the surgeon may find that the sac has been entered and that the dissection has to be completed from within. In this situation, two-thirds of the diameter of the sac is free of cord structures and is divided transversely, with fine artery forceps being applied to the proximal cut edge. The remaining third has to be dissected off the underlying cord structures. This is difficult because of the extreme delicacy of the thin-walled sac (Figure 16.4c). Once the circumferential division is complete, the proximal sac is ready for dissection off the cord.

A single pair of artery forceps can now be placed on the isolated proximal sac and gently retracted away from the cord structures. Allis forceps around the vas and vessels provide useful counter-traction. Fine areolar strands are divided and the sac is separated from the cord as far proximally as is possible. The dissection can be carried up to the neck of the sac without opening the short inguinal canal of an infant or very young child. When the sac is transfixed, divided and released, it will retract through the canal to lie inside the deep ring. Great care must be taken to avoid inclusion of vas or vessels in the transfixion stitch.

The identification and isolation of a *narrow persistent processus vaginalis* is usually straightforward. It appears as a pale, thin-walled, translucent tube of 1–2 mm diameter. The testicular vessels appear blue and the vas, although of similar diameter, can be identified as a palpable cord. The processus is picked up and divided. Hydrocoele fluid empties from the distal cut end. In the less common encysted hydrocoele of the cord, it is preferable to follow the distal cut end to open the cystic swelling but, in the more common hydrocoeles around the testes, the distal end is simply dropped back into the wound and left *in situ*. The proximal end of the patent processus is transfixed after the same dissection as for an infantile hernia.

The high operation

In this procedure, the cord is approached within the inguinal canal through an incision in external oblique. A skin crease incision is made over the deep inguinal ring and the external oblique is opened in the same line. This incision is only 1–2 cm in length and is not extended to the superficial ring. The internal oblique is then split at its junction with the cremaster muscle. The cremaster muscle and the internal spermatic fascia are then opened to expose the sac and the structures of the cord, which are lifted forwards into the wound. Thereafter, the dissection is similar to that in the low operation.

The preperitoneal operation

In this approach, the skin incision can still be placed inconspicuously, like for the low operation, but must be longer. After incision through Scarpa's fascia the upper flap is raised off the external oblique for 2–3 cm. A transverse muscle-splitting incision is then made through external oblique, internal oblique and transversus. The neck of the sac is then approached from above, by dissection deep to the abdominal wall muscles. The transversalis fascia must be divided to ligate the sac flush with the parietal peritoneum. It can either be divided before the dissection and lifted with the rest of the abdominal wall or be left to support the thin peritoneum during dissection and divided only once the sac has been identified in a more superficial plane.

Inguinal herniotomy in the female child

In the young girl or baby, an ovary or the fimbrial end of a Fallopian tube can prolapse into the sac. The ovary is frequently irreducible and may be mistaken preoperatively for a lymph node. Inguinal herniae are common in androgen insensitivity (formerly testicular feminisation) syndrome, and sex chromosomes should be checked in female children with bilateral irreducible inguinal herniae containing gonads. A female child may present with an enlarged labia rather than a groin swelling; this is due to incomplete closure of the canal of Nuck allowing fluid or bowel to herniate from the abdomen into this area. The operation is similar to that in the male, but the sac is easier to dissect in the absence of fine cord vessels that need to be safeguarded. Care must still be taken to avoid injury to a herniated ovary or tube, which must be returned into the peritoneal cavity.

Incarcerated infantile inguinal herniae

An incarcerated hernia can usually be reduced by sedation of the baby, followed by gentle manual reduction. The contents are most commonly loops of small bowel. If non-operative reduction is achieved, surgery should ideally be delayed for 48–72 hours to allow the oedema to settle. Further delay risks recurrent strangulation. A preperitoneal approach may be preferable when there has been a recent episode of strangulation, as it avoids the need to dissect a friable oedematous sac. Emergency herniotomy is essential if reduction is not achieved. At operation, the reduction is usually straightforward and a simple herniotomy is all that is required. The infantile gonad is more vulnerable to strangulation than the bowel and subsequent testicular infarction is not uncommon. Infarcted bowel requiring resection is rare. When bowel cannot be reduced at operation and viability is in doubt, it is very difficult to release and repair the neck of the peritoneal sac in the same fashion as in an adult. An additional separate laparotomy approach may be the safer option. If a resection and anastomosis is indicated, it can also be performed more satisfactorily by this approach, as it is difficult to return an anastomosis through the small deep ring.

FEMORAL HERNIAE

Femoral herniae occur most frequently in adult women because their femoral ring is wider than that in men. These herniae are less common in men and are rare in children. However, in both sexes and at all ages, femoral herniae are less common than inguinal herniae.

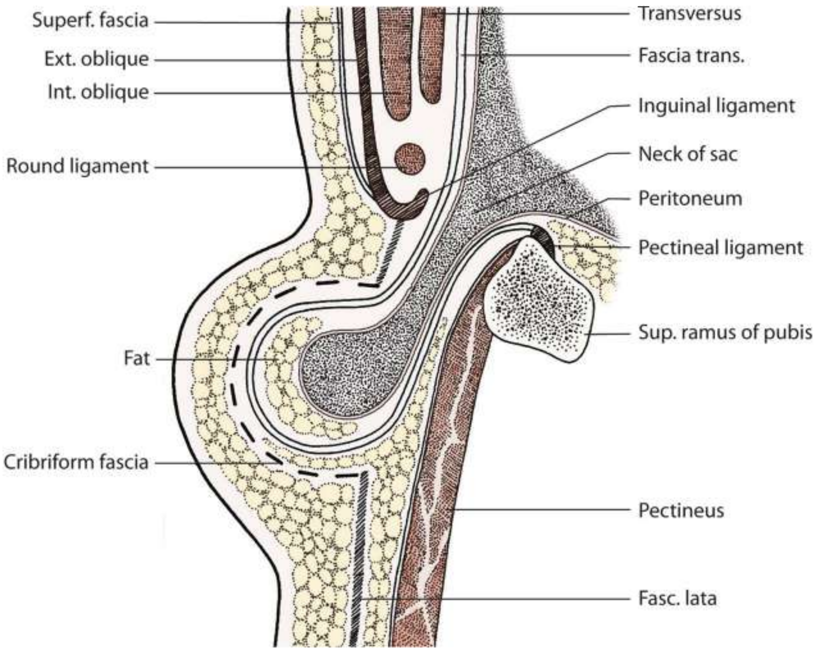
ANATOMY

The *femoral canal* is the medial of the three compartments of the femoral sheath, which is formed by a prolongation into the thigh of the fascia transversalis and the fascia iliacus, which line the anterior and posterior abdominal walls, respectively. The lateral compartment of the sheath contains the femoral artery and the intermediate compartment contains the femoral vein. The internal orifice of the femoral canal is the *femoral ring*. It is relatively rigid, as it is bounded anteriorly by the inguinal ligament, posteriorly by the pectineal line of the pubis and the fascia overlying pectineus, and medially by the free edge of the lacunar ligament. Laterally, it is bounded by the femoral vein. The ring is normally occluded by a pad of fat containing lymphatic tissue.

The hernia descends through the femoral canal and then turns forwards through the saphenous opening in the fascia. The cribriform fascia, which covers the opening, is thinned out in front of it. The hernia may then turn upwards and laterally to overlie the inguinal canal. The femoral ring is narrow and many herniae are irreducible from the time of presentation. The potential for strangulation is high and surgery should be advised.

The low operation

In this procedure, the incision is made 1 cm below, and parallel to, the medial portion of the inguinal ligament. A lipoma-like swelling is immediately encountered covered with thin fascia (Figure 16.5). Dissection around this leads to the femoral canal and confirms that it is a femoral hernia and not a lipoma. The actual sac is often surprisingly small and is deeply embedded in the condensed fatty tissue contained within the stretched cribriform fascia. The sac is isolated by incision into these tissues. It is freed to its neck then opened at the fundus, and any viable contents are returned to the abdominal cavity. Omentum is often adherent to the sac and needs to be separated. Alternatively, if it is free at the neck but adherent at the fundus, the adherent portion can be removed with the sac. When the neck of the sac is constricted by a tight femoral ring, it can be released by an incision medially into the lacunar ligament, but an aberrant vessel on its surface will occasionally cause troublesome bleeding. Temporary division of the medial end of the inguinal ligament is occasionally justified in very difficult circumstances. The neck of the sac is freed from the

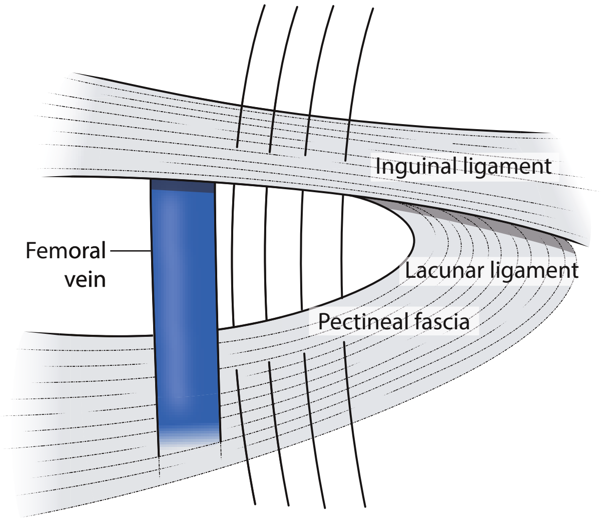


16.5 The anatomy of a femoral hernia. The fat beneath the thin cribriform fascia presents at operation as a lipoma-like swelling. ⏎

margins of the canal and then transfixed and ligated as high as possible so that it retracts above the canal.

The femoral ring palpated from below feels triangular, with semi-rigid anterior and posterior walls that meet at a very short medial wall. The femoral vein forms the soft lateral wall of the triangle. Complete closure of the femoral ring itself with sutures is seldom possible, as even if the anterior and posterior walls can be pulled into apposition, the femoral vein will be compressed and partially occluded. A compromise is the placement of two to four sutures across the ring from the fascia over pectineus muscle posteriorly to the inguinal ligament anteriorly. A J-shaped needle may make the placement of these sutures easier, and the femoral vein can be protected throughout by a finger placed over it. The sutures are all inserted before any are tied. The most medial suture is tied first and ligation is continued laterally until it is judged that tying the next suture would compress the femoral vein (Figure 16.6). Any remaining untied sutures are then removed. A small plug of mesh that is inserted before these sutures are placed will give extra security, but recurrence of femoral herniae is surprisingly uncommon.

Although viable bowel can be released and returned to the abdomen, and infarcted omentum can be excised, this approach is probably unsuitable for a strangulated case where infarcted bowel may be encountered; even if it is possible to draw healthy tissue down for the resection, it is unlikely that the anastomosis can be returned through the femoral ring and an additional higher incision becomes necessary.



16.6 Right femoral hernia repair. Sutures placed between the inguinal ligament and the fascia overlying the pectineus muscle close to its attachment to the pubic bone can be used to obliterate the femoral ring. ⏎

The high operation

There are several operations described that all involve approaching the neck of the sac from above, through the preperitoneal plane. The main advantage is better access to herniated bowel for assessment of viability and, if required, resection. The two older, classical approaches both have major disadvantages and have been abandoned:

1. The *Lotheissen approach*, through the conjoint tendon, inevitably weakened the inguinal canal.
2. The *McEvedy approach*, through a vertical incision in the anterior rectus sheath near its lateral border, was via a vertical skin incision across the groin crease, with subsequent troublesome wound healing.

The present standard high operation is a preperitoneal approach similar to that described above for an inguinal hernia. It is suitable for an open or a laparoscopic operation, gives excellent access for a mesh closure of the femoral canal and is now the method favoured by many surgeons for all femoral herniae. In a strangulated case, the peritoneum can be easily opened to check viability and resect if necessary. Only very occasionally does it prove impossible to draw infarcted bowel up into the wound, necessitating an additional lower incision to remove the gangrenous loop from below.

INGUINAL LYMPH NODES

ANATOMY

The *superficial inguinal lymph nodes* form a horizontal group below the inguinal ligament and a vertical group along the upper 5–8 cm of the great (long) saphenous vein. They drain the superficial tissues of the lower abdominal wall, lower limb and perineum. The *deep inguinal lymph nodes*, three or four in number, lie along the proximal end of the femoral vein and in the femoral canal; they drain the deep tissues of the lower limb. The superficial and deep nodes drain into the external iliac nodes.

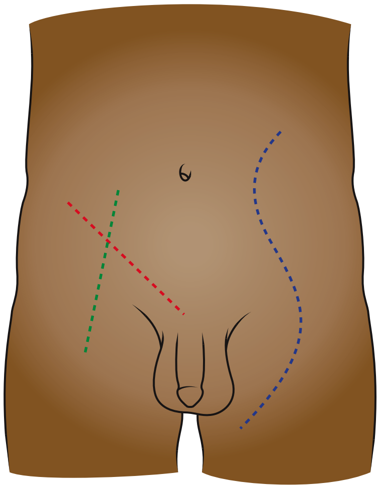
Excision biopsy

An excision biopsy of an inguinal node is undertaken for histological diagnosis. An enlarged node may be selected or a *sentinel node* identification technique may be employed, as described in the section on malignant melanomas in Chapter 4A.

Inguinal node dissection

This is undertaken as a potentially curative operation when malignant spread is believed to be only to these nodes. It can also be used as a palliative procedure to gain local control of a malignancy. It must be remembered in both scenarios that the division between inguinal and external iliac nodes, which are in direct continuity, is artificial. Malignant melanoma and squamous cell carcinoma of the anus, vulva and penis are tumours for which this operation is most likely to be considered. There is significant morbidity following radical inguinal node excision. Complications include skin breakdown because of poor blood supply to skin flaps, subcuticular lymph collection despite postoperative vacuum drainage, and late lymphatic oedema of the lower limb.

Operative procedure The skin incision may be oblique, vertical or curved (Figure 16.7). Skin flaps must then be elevated so that all but the most superficial subcutaneous fat can be excised from the groin. The upper limit of this excision is 5 cm above the inguinal ligament, where a transverse incision is made through the fat to expose the external oblique. All fatty, fascial and nodal tissue distal to this incision is then stripped off the external oblique aponeurosis down to the level of the inguinal ligament, securing superficial vessels crossing the field. Distally, a skin flap is raised so that the long saphenous vein is exposed. If the saphenous vein is to be removed with the nodes, it is ligated and divided between ligatures at least 10 cm below the inguinal ligament. Its stump is then turned upwards together with all the surrounding fat and lymph nodes. Some surgeons preserve the vein in an attempt to reduce lower limb oedema, but the subcutaneous tissue must still be divided at the same level to remove all of the fat and lymph nodes. The partially separated tissue is then stripped from the inguinal ligament, from the lateral to the medial side. If the long saphenous vein has been divided, it is divided again at its junction with the femoral vein, and small arteries arising from the femoral artery are also divided. The femoral vessels are exposed and all fatty and nodal tissue is cleared away from the medial side of the femoral vein and from the femoral canal. Haemostasis is secured and the skin flaps are closed over vacuum drains through which lymphatic drainage is usually substantial and may persist for some weeks. The operation may be combined with a further dissection of the iliac nodes, as discussed in Chapter 14.



16.7 Incisions for a radical inguinal node dissection. ⏎

SURGERY OF THE TESTIS, SCROTUM AND EXTERNAL GENITALIA

In previous editions, discussion of these topics featured in this chapter. Whilst there is significant overlap between the general, urological and paediatric surgeon, to reflect the development in thinking and approach, these topics have been moved and are discussed in their own chapters.

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17

Emergency abdominal surgery and trauma

Srujan Sharma

INTRODUCTION

A patient presenting to an emergency service with an 'acute abdomen' poses a unique challenge to the treating team. While surgery is often needed to treat the patient, the surgeon must make a series of frequently complex decisions without the luxury of time. This includes how to investigate the source of the pathology, how best to resuscitate or optimise the patient and if the surgery should be considered urgent or an emergency. It is also prudent to consider whether the set-up available is capable of providing the necessary treatment or whether the patient should be transferred to another hospital with more resources and expertise. Even if another centre is better equipped to provide certain care, the transfer itself may not be safe, or feasible, for a variety of reasons. Therefore, a surgeon must be able to evaluate if transfer is safe and feasible while also being prepared to provide the best possible care that is available in the facility where the surgeon works and the patient has presented. The best quality in emergency care requires adequate preparation and planning for urgent and emergency events, before the event occurs, akin to how institutions, agencies and even nations prepare for disasters and emergencies. In this context, the surgeon needs to know what their institution is capable of, what resources are available, what (if any) local protocols exist and how best to optimally use local guidelines and protocols. It is also important to note that the emergency surgeon leads a team, which in higher income countries or regions may include several specialists such as emergency physicians, acute care surgeons, interventional radiologists, trauma anaesthesiologists and surgical intensivists or, at the very least, a surgeon, an anaesthesiologist and appropriate nurses. This requires effective communication between team members. For example, a surgeon may want urgent surgery for a patient with intestinal perforation, but these patients benefit from preoperative resuscitation with intravenous fluids and may need central venous access or invasive arterial blood pressure monitor placement. In contrast, in active intra-abdominal haemorrhage, the anaesthesiologist must allow the surgeon to rapidly establish vascular control with little more than adequate intravenous access, a definitive airway and general anaesthesia. Such conflict of interest in the management plan of the patient must be openly discussed, and a compromise must be achieved swiftly. These are also situations that are best addressed by protocols agreed upon by all team members beforehand.

Nevertheless, while there is little doubt that treatment protocols and preparation provide the best framework for care, emergency surgery occasionally needs rapid 'outside the box' thinking. When the surgeon determines that emergency intervention (in less than ideal circumstances) is best for the patient, it is prudent to pause and communicate the rationale behind this decision to all team members and, if possible, discuss the details with another surgeon.

While the best chance of success may be abdominal surgery in many situations, this is major surgery and the decision to operate in an emergency is often difficult. Intra-abdominal haemorrhage, whether intraluminal or intraperitoneal, although increasingly managed by non-operative treatments, often still requires surgery for traumatic or other conditions. Likewise, emergency abdominal surgery is most commonly the best solution when the integrity of the gastrointestinal wall, as a physical barrier, is at risk or has already been breached. This situation can arise from a variety of inflammatory, neoplastic or traumatic (including iatrogenic) conditions. However, intra-abdominal infection, in the absence of overt or threatened perforation, can often be successfully managed with antibiotics. Radiologically placed drainage of an abscess or collection, if available, can often avoid the need for surgery. Certain conditions, such as acute cholecystitis, can be managed conservatively initially with non-operative treatment and elective surgery performed in a planned manner, especially when expertise and equipment are unavailable at the initial presentation.

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With these principles in mind, over the course of this chapter, we will focus on:

- Preoperative preparation in emergency abdominal surgery
- Common conditions causing an acute surgical abdomen
- Principles of emergency abdominal surgery
- Concepts in the management of abdominal trauma
- Damage control for the general surgeon

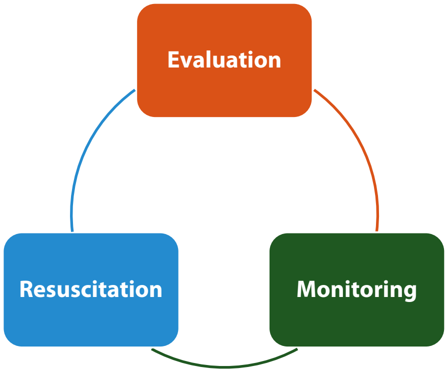
PREOPERATIVE PREPARATION IN EMERGENCY ABDOMINAL SURGERY

DIAGNOSING AND TREATING AN 'ACUTE ABDOMEN'

Approximately 10% of patients presenting to emergency departments (EDs) have acute abdominal conditions. Variously defined, an 'acute abdomen' is a non-traumatic condition with a recent onset of abdominal pain and associated symptoms pointing to an abdominal pathology and one that requires urgent medical or surgical attention. An acute abdomen is by far the most common problem that a general surgeon is called upon to treat in the ED and is of particular concern, as accurate diagnosis can be challenging, and inappropriate or delayed treatment can be devastating.

The primary goal in the ED in a patient with an acute abdomen is rapid identification of the aetiology of the process and an expedited decision on whether the condition warrants intervention. While the intervention required is often a surgical one, it is prudent to remember that knowing when not to operate is often far more difficult than performing a laparotomy.

The preoperative preparation of a patient with an acute abdomen involves three aspects: evaluation, resuscitation and monitoring. While these are all best done simultaneously (Figure 17.1), and there is considerable overlap, for the sake of simplicity, the three are discussed separately below.



17.1 Simultaneous preparation. ⏎

EVALUATION

Several detailed algorithms, guidelines and resources are available to help guide the evaluation of acute abdominal conditions; a detailed discussion of each pathological condition is outside the remit of this chapter. However, a basic five-step diagnostic approach is outlined below:

1. Ascertaining the patient's stability
2. Locating the anatomical origin of the process
3. Differentiating between a localised and a diffuse process
4. Making a differential diagnosis
5. Ordering appropriate diagnostic tests

Stability

All patients presenting to an ED must be triaged using a system that includes assessment of their haemodynamic status. In an acute abdomen, the stability of the patient will determine both the nature of investigations and the urgency of intervention. Emergency interventions for septic, or haemorrhagic, shock often preclude clinical evaluation of subtle abdominal history and examination findings. There is no justification for delaying interventions such as analgesia or intubation because of a concern about masking clinical signs.

In unstable patients, rapid bedside diagnostics, such as ultrasound and blood gas analysis, if available, are extremely useful tools. Basic laboratory tests such as haemoglobin, white cell count, serum electrolyte levels and renal function tests are usually rapidly available and must be requested promptly. When suspecting septic shock, it is worthwhile collecting a blood culture along with these laboratory tests prior to initiation of an appropriate broad-spectrum antibiotic. The choice of antibiotic is best determined by pre-existing knowledge of local susceptibility patterns.

A clinical history should be collected from the patient or their attenders, if available, and a rapid abdominal examination should be performed. Even in an obtunded or intubated patient, an intra-abdominal surgical cause for septic shock will usually have some clinical signs, such as distention, absent bowel sounds or dullness on percussion suggesting free fluid. Ultrasound of the abdomen, if available, can be useful as an extension of clinical examination. Portable radiographs may sometimes reveal free intraperitoneal air or signs of bowel obstruction but have poor overall accuracy. Electrocardiography must be performed in all seriously ill patients to exclude inferior wall myocardial infarction as the primary pathology.

In a patient with a history of abdominal pain prior to collapse, if the cause of instability is determined to be septic shock and treated to the best possible level in the ED, the next useful intervention, when available, is an abdominal computed tomography (CT) scan with intravenous contrast . In a collapsed patient, this may involve initiation of an inotropic agent in the ED, and a surgeon or anaesthetist may be required to accompany the patient to the CT scanner. If a CT scan is unavailable, or not feasible, and clinical and available assessments point to an abdominal cause, the patient must be taken for surgical exploration without fear of a 'negative' laparotomy. If the haemodynamic state of the patient and surgical expertise allows, diagnostic laparoscopy is a useful, less invasive, tool in these situations. It is important to note that a CT scan is not necessary before laparotomy in patients with frank peritonitis and almost always delays surgery. However, when diagnosis is in doubt, and when the facility is available, a prompt CT scan with intravenous contrast can help the surgical team to prepare appropriately for emergency surgery or consider other interventions such as radiological drain placement. Volume resuscitation by intravenous fluids should continue while the CT is being performed and, ideally, one of the surgical team should stay with the patient. The addition of oral contrast is time consuming and rarely offers additional information in the setting of an acute abdomen.

If the patient has an intra-abdominal cause for haemorrhagic shock that does not respond to first-line resuscitation (1 L of crystalloid fluids and/or one unit of blood), they must rapidly be transferred to the operating room (OR) for haemorrhage control. Patients with haemorrhagic shock that respond to initial resuscitation benefit from a CT with intravenous contrast, especially when interventional radiology facilities are available as a definitive or preoperative treatment. However, when the bleeding is from a ruptured ectopic pregnancy or an abdominal aortic aneurysm, which are both conditions that can be diagnosed via bedside ultrasound, the patient should be moved to the OR for control without delay.

Origin

In patients with stable vital signs, a detailed history and thorough clinical examination are mandatory for efficient diagnosis of the pathological organ of origin in the acute abdomen. The patient's history, in addition to clinical examination findings localising the origin of the pain to a quadrant or region of the abdomen, provides a good starting point for decisions on testing. Right upper quadrant pain often originates from the hepatobiliary system, whereas pelvic pain has other differential diagnoses. Other factors such as the sex of the patient, underlying conditions, previous surgery, medications and antecedent events also help in deciding which tests to perform and the possible organ of origin. For example, all women of reproductive age must have pregnancy ruled out by a pregnancy test. Clinical evaluation may also help to diagnose patients in whom the abdominal pain is referred from extra-abdominal pathologies such as testicular torsion, pleuritis, hernias and herpes zoster infection (shingles).

The decision on laboratory testing is based on the clinical differentials and the expected time that the test results will take. Time-consuming tests such as magnetic resonance imaging (MRI) scans are often of no practical use in an ED setting, and their use must be restricted to special situations.

Extent

The prior clinical evaluation should have revealed several clues as to the organ of origin, possible aetiology and extent of pathology. Differentiating localised or 'walled off' pathologies from diffuse pain or generalised peritonitis helps in deciding if the patient needs upfront major surgery or more focused testing to plan less invasive or, in some patients, non-invasive treatments. For example, pain in the right lower quadrant with subtle rebound tenderness could warrant Alvarado scoring and ultrasound examination for appendicitis, but the same history with diffuse board-like rigidity suggests free rupture, and urgent surgery must be planned. Similarly, acute calculous cholecystitis may be managed non-operatively in the acute setting, but a ruptured gallbladder with peritonitis warrants surgical intervention. It must be remembered that there are conditions, apart from peritonitis, that present with diffuse abdominal pain. These range from mechanical bowel obstruction to infective gastroenteritis, as well as to rarer causes such as acute intermittent porphyria and narcotic bowel syndrome. Having stabilised the patient and initiated basic measures such as analgesia, intravenous fluids and antibiotics (if indicated) allow some time for decision-making.

Differential diagnoses

At this point, it is prudent to pause and list all of the differential diagnoses in the order of probability. All relevant details in terms of age, sex, underlying conditions and previous medical history should be documented, together with the history of presentation, such as temporal details, site of origin and associated symptoms. The discussions given in the sections on stability, origin and extent of pathology would have also suggested or ruled out certain pathologies. While summarising all of the information and crystallising differential diagnoses can be challenging in emergency settings, it is crucial in clinical practice. Prior preparation and planning, aided by increasingly available online resources and rapid bedside testing, can aid the process.

Remember that assessing the acute abdomen, like all triage, is a dynamic process, and the surgeon needs to be prepared to act upon new information such as new clinical instability and should not be misled by transient improvement, at least until likely certainty is achieved in diagnosis and definitive therapy initiated.

Testing

The basic principles of ordering laboratory and radiological tests remain the same in acute abdominal conditions as in other areas of medicine. Tests should be as sensitive and specific as possible while remaining accessible. However, like in other emergency conditions, expediency is also desirable. Many patients with an acute abdomen, at this stage, may already have been tested with 'point-of-care' blood tests (glucose, lactate, blood gas analysis, etc.) and urine tests (ketones, pregnancy test, pH, etc.), may have had some form of radiological imaging (bedside ultrasound and radiographs) and may be connected to monitors for electrocardiography, saturation and blood pressure monitoring. Further tests ordered should help confirm diagnosis urgently and, if possible, aid in surgical decision-making. Tools such as the American College of Radiology (ACR) Appropriateness Criteria® for variants of non-localised and localised abdominal pain may be used to guide imaging. Algorithms are available online to aid with test planning for diffuse non-localised abdominal pain or localised pain for each region. However, repeat clinical examination by an experienced surgeon is the cornerstone of assessment and management of a patient with an acute abdomen.

Finally, when no other recourse is available, an acute care surgeon must not forego making a decision to explore the abdomen via laparoscopy, or laparotomy, to confirm and directly treat the pathology, rather than risking morbidity or, at times, mortality from delayed intervention.

RESUSCITATION

It is a true and accepted adage that resuscitation should start as quickly as possible in emergency settings. Upon triage, if a patient is found to be unstable, resuscitation takes precedence over confirmatory diagnostics to ensure optimal outcomes. Resuscitation in the patient with an acute abdomen involves rescuing the patient from the physiological crisis caused by an abdominal catastrophe to a point where definitive diagnostics and therapeutics can be performed. While resuscitation on its own is a major scientific and practical entity, a few key concepts and goals that are important in abdominal conditions are outlined below.

Fluid and electrolytes

Most emergency abdominal pathologies feature patients who present with a net negative fluid balance. This is often from a combination of excessive losses from vomiting or diarrhoea and a decreased fluid intake. It is important to clinically recognise dehydration and shock and to treat it appropriately. Additionally, patients also have electrolyte abnormalities that will direct intravenous fluid therapy, and a bedside arterial blood gas analyser can be invaluable in the ED.

As a rule, balanced crystalloid solutions are the fluid of choice in resuscitation before surgery. A baseline volume of fluid (isotonic saline or Ringer's lactate) can be started empirically with 500 mL to 1 L as a fluid challenge in most adults, while more specific calculations are made based on the patient's weight, estimated fluid lost, electrolyte levels and dynamic monitoring of vitals and urine output, as discussed below. Most adults with severe losses from acute gastroenteritis or peritonitis will have lost several litres of volume from the extravascular space prior to arrival in the ED. The aim of fluid therapy is to restore what has already been lost while replacing ongoing loss, in addition to maintenance of fluid requirements, to ensure adequate organ perfusion and therefore reduce or prevent end organ damage. A general guideline is a 1:1 replacement for losses. However, it is best to monitor each patient dynamically, as fluid overload causing pulmonary oedema is a real possibility, especially in older people and those with suboptimal cardiac function.

It is safest to direct electrolyte correction once blood gas analysis or laboratory values are available. As stated, abnormal electrolyte levels are common with intestinal losses, but aggressive empirical correction, without laboratory confirmation, is generally not advisable. Common abnormalities are hypokalaemia from upper gastrointestinal losses, hyperchloraemia from over correction with normal saline and bicarbonate loss leading to acidosis. Every emergency clinician must be comfortable in reading and analysing an arterial blood gas report to recognise and treat metabolic abnormalities in patients with an acute abdomen and in shock.

Blood and blood product transfusion

Intra-abdominal haemorrhage, whether traumatic or non-traumatic, often requires transfusion of blood and blood products in the ED. This means that the centre receiving the patient ideally should have an equipped, and functioning, blood transfusion centre or at least some blood storage capabilities. When there is no blood available, treatment options for such patients are limited and survival may be compromised. If a surgeon is faced with this extreme situation, it is important to know what transfer capabilities are available. If referral and transfer is not possible, it is advisable to operate as early as possible. For example, a substantial proportion of patients with solid organ trauma can be treated non-operatively with close observation and transfusions if optimal imaging and care facilities are available. When a patient has known internal bleeding, and surgical referral and transfer is not feasible, there may be benefit in laparotomy to attempt haemorrhage control and consider auto-transfusion of blood (provided there is no intestinal content contamination). Continuing to give crystalloids alone in these patients is not beneficial and will only lead to dilutional coagulopathy. However, auto-transfusion is not easy to set up without prior planning and the Advanced Trauma Life Support© (ATLS) guidelines still recommend transfer when capabilities are lacking.

In more resource-rich settings, a viscoelastic assay in the ED is a point-of-care test that helps rapid decision-making in haemorrhagic shock. While the whole clotting process can take some time to analyse, a lot of critical information is available within minutes. If this assay is not available, current ‘massive transfusion protocols’ in ongoing traumatic and non-traumatic intra-abdominal haemorrhage generally recommend a balanced 1:1:1 ratio of packed cells, fresh frozen plasma and platelet transfusion. Protocol-based transfusions can be adapted to parameter-directed transfusions as soon as results are available. In a remote setting, if available, O-negative whole blood is the best choice prior to transfer. Certain specific conditions, such as postpartum haemorrhage and haematological disorders, have different guidelines for transfusion.

Blood product transfusions may also be required in non-haemorrhagic conditions where surgery is needed for other indications, but the patient is found to be anaemic. A minimum preoperative target of 7 g/dL is recommended (8 g/dL in those with cardiac illness) with additional blood arranged, depending on expected surgical blood loss. Other underlying conditions such as chronic liver disease or pre-existing thrombocytopenia may require plasma or platelet transfusions.

Adjunctive treatments

Additionally, a few simple interventions prior to emergency abdominal surgery help to optimise the outcome. The first is ensuring steps to optimise blood glucose levels. Both hypoglycaemia and hyperglycaemia are common in the emergency setting and can be rapidly detected bedside. Corrective measures must be started upon recognition of a significant deviation.

Most acute abdominal conditions involve sepsis, or the risk of intra-abdominal sepsis, from intestinal flora. Patients in septic shock require broad-spectrum antibiotics based on local recommendations and susceptibility patterns. Current recommendations for most clean abdominal procedures suggest at least the optional use of preoperative cephalosporin to reduce surgical-site infection rates. Most patients who are not in shock, but have acute abdominal conditions needing surgery, more often than not are at risk of infection from intestinal flora and will require additional preoperative prophylaxis with anaerobic coverage in addition to Gram-negative cover. Antibiotics need to be de-escalated or discontinued postoperatively if there is no underlying sepsis and no intraoperative spillage, and any free fluid found within the peritoneal cavity should be sent for culture to guide further therapy.

Patients with septic shock also benefit from inotropic usage prior to surgery to reduce end organ damage. While evidence currently does not support the use of inotropes for haemorrhagic shock from abdominal trauma in the ED, inotropes are recommended once the patient is in the OR and haemorrhagic control is under way. While a single inotropic agent may be started on a dedicated peripheral line, most patients will benefit from central venous access through the subclavian or internal jugular veins. When central venous access is performed in a controlled environment such as an OR, a multi-lumen system is preferred, as it allows the sterile sealing, and isolation, of one lumen for parenteral nutrition, should parenteral nutrition be needed post surgery. Femoral venous access is technically easier, but inferior in quality and safety in terms of inotropic use, central venous pressure monitoring and use for parenteral nutrition.

Most non-traumatic acute abdominal conditions need little else in terms of preoperative intervention apart from good venous access, gastric and urinary catheter placement, non-invasive monitors and connection to a face mask with an oxygen source. Some patients in shock who are obtunded, or in respiratory failure, secondary to abdominal hypertension or acute respiratory distress syndrome will require a definitive airway with endotracheal intubation in the ED. Abdominal trauma is often associated with other injuries, and those patients may require additional procedures such as securing the airway, cervical spine control, breathing and ventilation prior to abdominal surgery for circulation or sepsis control as directed by ATLS guidelines. Invasive blood pressure monitoring through an arterial line, if indicated, can be established in the OR or intensive care unit (ICU) as needed and is rarely essential in an ED setting.

MONITORING

As stated at the outset, evaluation, resuscitation and monitoring should be simultaneous and, although discussed last, good monitoring of the patient's condition, and response to intervention, may be as important as diagnosing the cause of abdominal pathology and initiating resuscitative and definitive therapies. Bedside electronic monitors are relatively cheap and provide dynamic information about patient status with oxygen saturation probes and non-invasive blood pressure monitoring. Electrocardiography leads for continuous monitoring may have already been applied in unstable patients and, additionally, some monitors can calculate and record the respiratory rate. Other non-invasive monitors can also be used if available.

An important aspect of monitoring is to assess the response to intervention. Heart rate and blood pressure response should tend towards normal levels. Elevated serial lactate levels should show a declining trend. The quality and output of tubes such as the urinary and gastric catheters is also helpful. A target urinary output of at least 0.5 mL/hour/kg of body weight is a good marker to titrate crystalloid resuscitation. Central venous pressure can be calculated, and even monitored, electronically if venous access is established. Dynamic invasive monitoring with arterial lines helps accurately titrate inotropic infusion rates. Echocardiography and other ultrasonic investigations, if available, are easily done bedside, are repeatable and non-invasive, and are increasingly replacing invasive monitors such as Swan–Ganz catheters in the emergency setting.

Monitors help assess the patient's response to diagnostic and therapeutic manoeuvres and can be helpful in rapidly recognising failure, or deterioration, in a dynamic situation. For example, sudden tachycardia and a precipitous fall of blood pressure in a patient waiting to be evaluated for abdominal pain suggests free intraperitoneal haemorrhage and needs urgent surgical treatment. Conversely, a patient with known ruptured peptic ulcer disease, whose monitors show good response to interventions, is best optimised prior to laparotomy.

COMMON CONDITIONS CAUSING A 'SURGICAL ABDOMEN'

In the previous section on preoperative preparation, a general approach to emergency abdominal conditions was discussed, emphasising the increasing importance of simultaneous intervention while a diagnosis is being made. This does not mean that a specific diagnosis is not important, and every effort should be made to reach a plausible confirmation of the clinical condition while avoiding undue delay. An accurate diagnosis allows specific planning and may even help avoid unnecessary or untimely surgery. Consequently, an accurate diagnosis may transform the opinion that an acute abdomen is actually an 'acute surgical abdomen' needing surgical intervention. This section, although by no means exhaustive, discusses a few common non-traumatic emergency abdominal conditions. Abdominal trauma will be discussed later.

Broadly, there are only two main indications for emergency abdominal surgery. The first is bleeding and the second is infection from pus, or peritonitis (or the risk thereof) (see Table 17.1). Obstruction and bowel gangrene may also be considered as independent indications, but the underlying impetus in these situations is to prevent peritonitis and sepsis secondary to free perforation of intestinal content. For example, many patients with appendicitis and cholecystitis can be treated non-operatively, in the absence of free biliary or intestinal contamination.

Table 17.1 Indications for emergency abdominal surgery in non-traumatic conditions ⏎

Haemorrhage	Infection
Intraperitoneal	Intra-abdominal abscess
Intraluminal	Peritonitis (or risk thereof, from luminal obstruction or ischaemia)

EMERGENCY ABDOMINAL SURGERY FOR NON-TRAUMATIC HAEMORRHAGE CONTROL

A patient presenting to the ED with pallor and shock may have massive intra-abdominal haemorrhage. In the non-traumatic setting, the most common reasons for this are intraperitoneal bleeding from a ruptured ectopic pregnancy (Chapter 26) or intraperitoneal rupture of an abdominal aortic aneurysm (Chapter 18). Massive bleeding may also be retroperitoneal (from a local pathology such as a tumour or aneurysm, or because of deranged coagulation from medications or diatheses), and occasionally bleeding may be intraluminal. In selected cases, surgery may be needed.

Common concepts discussed in the section on preoperative preparation for these patients do not change between diagnoses. Stability is paramount. Patients who are stable at presentation, or respond to transfusion of a single unit of blood, may be imaged with a contrast-enhanced CT scan to aid diagnosis and allow interventional radiological intervention either as a definitive measure or as a bridge to surgery. All unstable patients must be taken to the OR as soon as possible. This includes patients who need massive ongoing transfusions of blood.

Emergency surgery in actively haemorrhaging patients generally requires a large midline laparotomy for expediency and access. Further physiological concepts are delineated in the section 'Damage control for the general surgeon'.

Spontaneous intraperitoneal haemorrhage

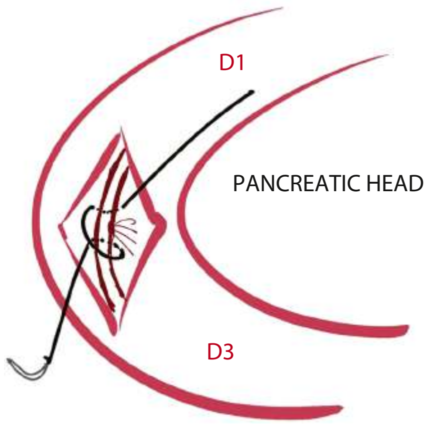
Apart from the two common conditions mentioned earlier, ruptured ectopic or ruptured abdominal aortic aneurysm and spontaneous intraperitoneal bleeding can occur from aneurysms (either primary or secondary from pathologies such as pancreatitis-related splenic artery aneurysms), from tumour bleeds or rarely from medication-related or pathological coagulopathies. While coagulopathy-related bleeds are usually intramuscular and contained, allowing for medical correction of the disorder and avoiding surgery, pathological bleeding from other conditions will involve laparotomy and surgical clamping and/or packing followed by organ-specific measures depending on the pathology. Importantly, damage control concepts should always be kept in mind and are discussed in detail below.

Retroperitoneal haemorrhage

Renal, adrenal, vascular and lymphoproliferative pathologies can occasionally present with spontaneous retroperitoneal bleeding. Retroperitoneal haemorrhage is usually contained, with the patient remaining stable unless free rupture into the peritoneum occurs, which is usually accompanied by haemodynamic collapse. If free rupture occurs, expedient surgery must proceed with the same concepts as intraperitoneal bleeding. However, prior to free rupture, most pathologies are usually amenable to some form of endovascular or interventional radiological therapy, even aiding eventual surgery for resection of the offending organ or repair of an aneurysm.

Intraluminal haemorrhage

Advances in endoscopic technologies and effective pharmacotherapy for peptic ulcer disease have largely reduced the indications for emergency surgical intervention for intraluminal bleeding. Most intraluminal bleeding, even if overt, arises from pathologies that are best dealt with endoscopically or with elective surgery.



17.2 Underrunning a duodenal ulcer. A figure-of-eight suture is placed under the bleeding point. ⏎

Occasionally, overt gastrointestinal bleeding that is unstable or requiring massive transfusions will require emergency surgical rescue. When the pathology is obvious – such as with a known bleeding duodenal ulcer that has failed non-operative interventions, obvious or palpable bowel pathology, or rarer situations such as haemorrhagic colitis – surgery must proceed to address the underlying cause. This may involve intraluminal surgery such as suturing of bleeding vessels at the base of a duodenal ulcer (Figure 17.2), excision of a lesion (most gastric ulcers or polyps) or larger gastrointestinal resections. Excised tissue must always be sent for pathological testing even if seemingly benign.

Overt unstable gastrointestinal bleeding of unknown origin requiring emergency surgery is rare. Surgery for obscure gastrointestinal bleeding is discussed in detail elsewhere (Chapter 13). Even in such situations, most patients should have had upper and lower gastrointestinal endoscopic evaluations ruling out pathologies in the upper or lower gastrointestinal tract. Small bowel pathologies that are not externally obvious will require 'on-table' enteroscopy in the OR, if available. In this situation, a mid-small bowel enterotomy is performed through which endoscopic evaluation is performed and the intraluminal pathology is localised. Once the site is localised, the offending segment is resected to control haemorrhage and the enterotomy is repaired if not within the resection margins.

After resection, decisions on primary anastomosis versus ostomies after such emergency resections in unstable patients can be challenging and are discussed below.

Postoperative haemorrhage

All surgical procedures, being inherently invasive, involve a risk of bleeding. The challenge with postoperative bleeding in the abdomen is that little may be obvious on external appearances while there may be devastating exsanguination internally. Clinical deterioration such as tachycardia may be erroneously attributed to postoperative inflammatory or nociceptive response, and a single, mild drop in haemoglobin level may be attributed to fluid shifts or intraoperative loss.

As with all haemorrhagic shock, all available information must be collected and interpreted. This includes the patient's haemodynamics, central venous pressure, urinary output, sonological assessment of inferior vena cava compressibility or echocardiographic changes, lactate levels, base deficit and haemoglobin levels. Gross abdominal distention develops late in abdominal haemorrhage and is difficult to interpret clinically when a patient has had major surgery. Finally, while active filling of intraperitoneal drains with blood may be definitive, the absence of the blood in the drains does not rule out haemorrhage, as the drain may be blocked with clots or kinked.

Primary postoperative haemorrhage happens within 24 hours of surgery and indicates operative failure of a ligature on a vessel or an unrecognised issue from the index surgery. Secondary haemorrhage occurs after a day and tends to be due to infection or coagulopathy. Early recognition of primary or secondary haemorrhage is aided by good vigilance, and successful control of bleeding requires timely intervention. The principles of operation for haemorrhage are the same as those listed above and are guided largely by haemodynamics and intraoperative findings.

In many centres, an acute care or 'on call' surgeon may be called in to perform surgical rescue on postoperative haemorrhage from surgery performed by another team, who may be unavailable at short notice. A rapid assessment of the patient's condition and simultaneous assessment of intraoperative issues must be done. This situation reiterates the importance of every surgeon dictating or documenting good operative notes prior to leaving the OR (or at least by the end of the working day).

EMERGENCY ABDOMINAL SURGERY FOR PERITONITIS

Most emergency surgery in the abdomen is for conditions that cause peritonitis, or the risk thereof. Following the principles outlined in the previous section on evaluation, if surgery is indicated, there should be little doubt that the team and centre can provide safe surgery, and that the team can provide the extent and type of surgery that the patient needs. Haemodynamically unstable patients with peritonitis (localised or generalised) benefit from a prompt laparotomy, and while described and successful in selected patients, time consuming and anaesthetically complex laparoscopy could be considered unnecessary and potentially dangerous, even in the most experienced centres. Laparoscopy does offer significant advantages in stable patients with peritonitis, even as a diagnostic tool, as a much smaller targeted incision may be planned, should the need arise to convert to open laparotomy.

A variety of conditions lead to or cause peritonitis, needing surgical treatment. For the purposes of this discussion, they are discussed under three broad headings:

1. Generalised peritonitis
2. Localised peritonitis
3. Impending peritonitis

Generalised peritonitis

Of the three broad conditions, in many ways surgery for generalised peritonitis is the most straightforward. Prior to surgery, a few alternative diagnoses should be contemplated and sought. Pancreatitis may present with clinical features suggesting generalised peritonitis and can almost always be ruled out fairly quickly by biochemical testing, and CT scans are also useful, if available. CT scans pick up even a tiny amount of free air, suggesting hollow viscus perforation, providing a strong indication for surgical intervention, especially when other diagnoses are present, such as severe gastrointestinal infections.

As stated earlier, in stable patients, laparoscopy is a good alternative to exploratory laparotomy with significant postoperative advantages in experienced hands, even in conditions with generalised peritonitis. Laparoscopic lavage can address all intraperitoneal areas adequately, intracorporeal repairs can be performed for some ruptured viscera and even resections can be performed provided the patient remains stable. Laparoscopy also offers the additional advantage of a targeted or reduced incision.

In patients who cannot tolerate laparoscopy, or when the facility is unavailable or difficult to set up as an emergency, traditional midline laparotomy remains the standard approach. While the nuances of emergency laparotomy are discussed in the following section, once diagnosis is confirmed, surgery proceeds on the pathological organ as needed. Common conditions depend on factors such as age, underlying conditions and geographical location. Perforated appendicitis, peptic ulcer disease, tuberculosis, and intestinal perforation from malignancies, ischaemia or mechanical obstruction from hernias all require lavage of gross contamination and repair or resection of the diseased organ.

Occasionally, no obvious cause is found, despite a complete exploration (e.g. primary group A streptococcal peritonitis), in which case fluid is collected for sampling and the patient is closed and treated with broad-spectrum antibiotics until new information emerges. A few other conditions such as Henoch–Schönlein purpura, mesenteric adenitis and early acute pancreatitis have visible findings (specifically bowel wall mottling, nodes and early saponification). Rarely, some conditions such as scrub typhus infestation can also present with peritonitis and result in what is termed a ‘negative laparotomy’. Such negative operations, while increasingly rare with systematic approaches and better diagnostics, are still preferable overall to delaying intervention when all signs point to intraperitoneal sepsis.

Localised peritonitis

Most conditions that cause generalised peritonitis initially present with localised features. If the patient presents early enough, some conditions are amenable to non-operative or minimally invasive methods. Early appendicitis, cholecystitis and diverticulitis can be managed with antibiotic treatment and do not need immediate surgery. Even when planning surgery in these patients, laparoscopy is the standard option. Laparoscopy also offers good access to determine gynaecological causes for abdominal pain (Chapter 26). In appendicitis specifically, resource-limited centres may still offer traditional open approaches through an incision in the right iliac fossa. If free perforation is found, or the appendix is found to be normal, this incision can be closed and a formal laparotomy can be performed if needed.

Localised peritonitis is common in the early stages of diverticulitis, which can be picked up radiologically or upon diagnostic laparoscopy. The surgeon then faces a choice on whether to treat the patient with antibiotics and risk a relapse or subject the patient to major resection and recovery from major surgery. Occasionally, smaller ‘contained’ perforations from Crohn’s disease or a malignancy may present with localised peritonitis as the body tries to wall off the infection with an inflammatory phlegmon. Such patients are usually stable and benefit from radiological assessment prior to surgery to decide if a percutaneous drainage will suffice. Repeated small bowel resections in patients with inflammatory bowel disease may lead to intestinal failure, and perforation of a malignancy may have upstaged the disease to a level that needs careful expertise, and possibly palliative decisions. Both sets of patients benefit from multidisciplinary and specialised care with optimal outcomes in elective settings. Nevertheless, the patient’s overall stability will decide whether intervention is needed in an emergency setting, as a patient in septic shock from an intra-abdominal collection may need surgical drainage if interventional radiology is not available or not feasible.

Conditions with impending peritonitis

These conditions often present the most challenging dilemmas to the emergency surgical team. Unlike in patients with established peritonitis, in whom preoperative stabilisation is warranted, or conditions with active haemorrhage, where surgical control is pivotal, conditions with impending peritonitis require a more individualised approach. Impending peritonitis involves conditions where the integrity of luminal viscera is at risk from infection, obstruction, ischaemia or a combination of all three. Therefore, it encompasses a variety of conditions such as:

- Infective pathologies such as typhoid ulcers, tuberculosis, intestinal worms, appendicitis or cholecystitis
- Mechanical pathologies such as closed-loop intestinal obstructions, intussusception or strangulated hernias
- Ischaemic pathologies such as arterial ischaemia from atherosclerosis or venous gangrene from a prothrombotic disorder

It is not uncommon for all three mechanisms to act in synergy. For example, an internal hernia secondary to a congenital band or band adhesion will start as mechanical bowel pathology, but ischaemia and infection can both ensue, even prior to technical perforation.

The management principles outlined in the previous section on preoperative preparation are as outlined above. These patients are usually stable and, unless the pathology is obvious clinically (e.g. strangulated hernia) on ultrasound imaging (appendicitis or cholecystitis) or on plain X-ray (with sufficient clinical information), patients generally benefit from dual-contrast CT scanning, if available. CT helps in decision-making on the urgency of the situation and can aid in the selection of the approach and/or incision. For example, a postoperative adhesion causing a closed-loop obstruction can often be dealt with laparoscopically, whereas extensive gangrene of the small bowel on CT might warrant a discussion on palliation without an operation. Some conditions may even be addressed to some extent non-operatively in the ED. For example, a nasogastric tube relieves simple intestinal obstruction, at least temporarily, until surgery can be planned, or taxis can be performed to reduce a non-strangulated inguinal hernia.

Other related, but distinct, entities are conditions that form pus within viscera. Most of these conditions are now managed non-operatively or with minimally invasive interventions in large centres; however, an emergency general surgeon may be called upon to drain these abscesses in resource-limited settings. Pyogenic liver abscesses, pyonephrosis, empyema and splenic abscesses are a few examples. If specialist referral is not feasible, the general surgeon must choose the safest and most feasible option in an emergency setting, and that may well be open drainage. Laparotomy for intra-abdominal drainage and open extraperitoneal approaches for retroperitoneal collections are both acceptable techniques. Impacted stones (ureteric or biliary) can be removed and the sepsis ameliorated safely through the same approaches, with the caveat that recovery time will be longer.

In general, most patients with impending peritonitis can have appropriate preparation, including transfer to a centre with more expertise or appropriately timed surgery. It is usually in the patient's interest that the operation takes place during the daytime with a full team of staff and equipment, as opposed to a skeletal or inexperienced team attempting major surgery out of hours.

PRINCIPLES OF EMERGENCY ABDOMINAL SURGERY

Once preoperative preparation is complete and a reasonable diagnosis achieved, all emergency abdominal operations can be broken down into three steps: access, assessment and action (Figure 17.3). The surgical aspects of the two possible approaches (i.e. laparotomy and laparoscopy) are briefly discussed in this section. A few essential practices for the surgeon in the OR before, and after, the surgery are as follows: to ensure that they are operating on the right patient, that the patient and team are adequately prepared and that the patient has been set up for an optimal outcome as far as feasible, in the available environment.

PREPARATION IN THE OPERATING ROOM

A few simple steps by the surgeon can greatly prevent unnecessary morbidity. As with all surgical procedures, the surgeon must do everything possible to 'set up for success'. A few steps for the surgeon to follow, once the patient reaches the OR, are discussed below.

ACCESS
ASSESS
ACTION

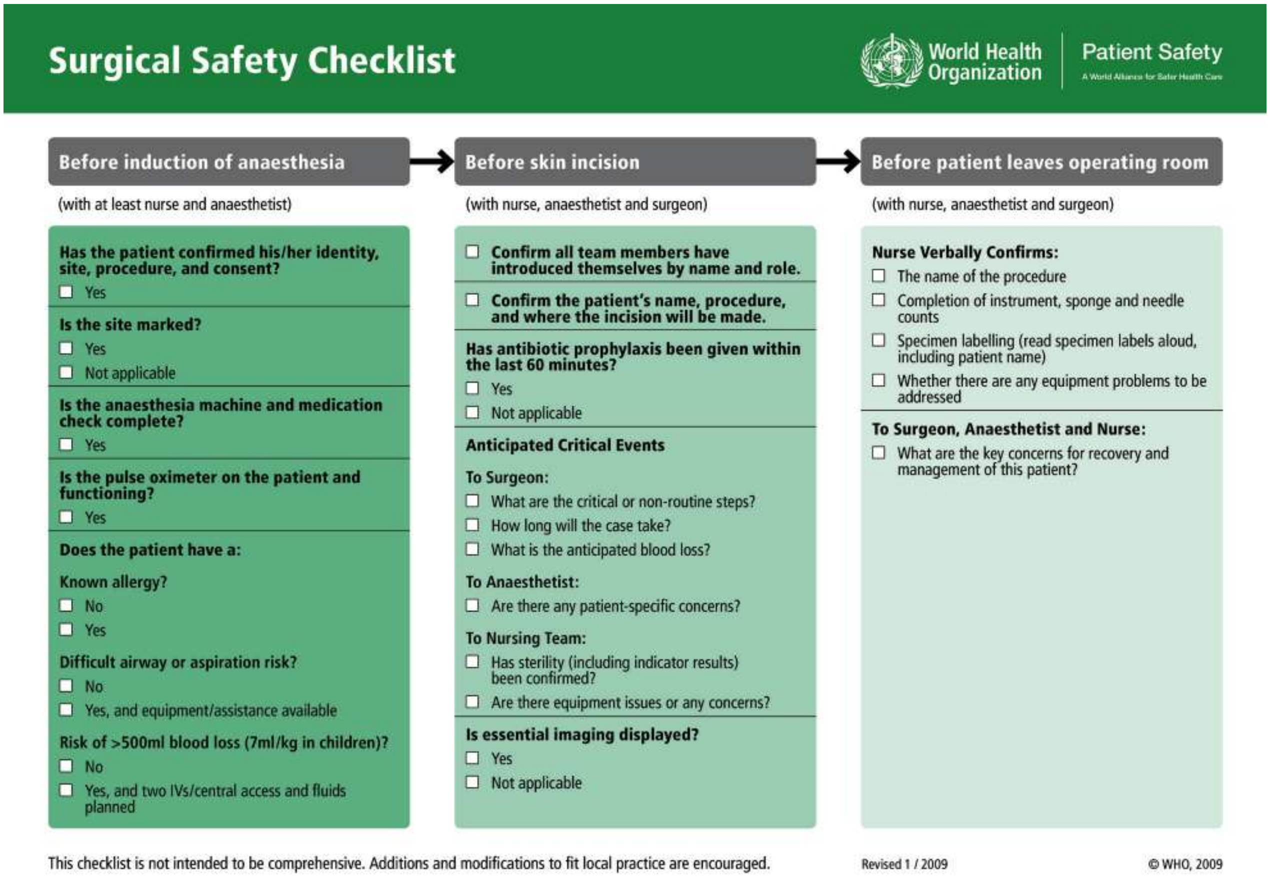
17.3 The three steps of all emergency abdominal surgeries. ⏎

Surgical safety checklist

The wrong surgery on the wrong patient is not something most patients and surgeons can envision happening in the twenty-first century. It is each surgeon's responsibility to make sure this never happens to their patients. The institution of the World Health Organization (WHO) surgical safety checklist (Figure 17.4) has been shown to have improved morbidity and mortality and, in some form or another, is used by most surgical providers across the globe. In an emergency setting, it is of even greater importance, as the chances of unforced errors increase significantly. After arrival in the OR, most patients are able to participate in the few moments it takes to confirm the patient's identity and proposed procedure in the presence of the scrub nurse, anaesthesiologist and surgeon. We cannot recommend emergency general surgical practice without such a preoperative 'time out'. Certain exceptions would be resuscitative thoracotomy (usually started in the ED) and damage control surgery in trauma; however, in both of these conditions, the same surgical team accompanies the patient from arrival in the ED to the OR and, therefore, an unindicated procedure is unlikely.

Positioning and prepping the patient in the operating room

While a supine position suffices in most situations, certain conditions may benefit from alternate options. The Lloyd-Davies position is an option that can be considered for most patients where pelvic pathology is likely. While both arms are ideally tucked into the sides of the patient, if vascular access is challenging, one or both arms may be left extended for the anaesthesiologist to facilitate vascular access. In 'crash laparotomies' (described below), our practice is to leave both arms out for the anaesthesia team while the abdomen is rapidly prepped and opened to arrest bleeding, and other steps proceed subsequently. If a laparoscopy is planned, strapping the patient's thighs or chest securely allows safe, and greater, manipulation of operating table angles to aid gravitation-assisted retraction of the bowel. It is also wise for an emergency surgeon to consider the usage of intraoperative devices such as external warming devices to reduce the risk of hypothermia in a long laparotomy or peritoneal lavage for contamination. Emergency operations carry an increased risk of venous thromboembolic complications, and if available an intermittent



Surgical Safety Checklist

World Health Organization | Patient Safety
A World Alliance for Safer Health Care

Before induction of anaesthesia

(with at least nurse and anaesthetist)

Has the patient confirmed his/her identity, site, procedure, and consent?
☐ Yes

Is the site marked?
☐ Yes
☐ Not applicable

Is the anaesthesia machine and medication check complete?
☐ Yes

Is the pulse oximeter on the patient and functioning?
☐ Yes

Does the patient have a:

Known allergy?
☐ No
☐ Yes

Difficult airway or aspiration risk?
☐ No
☐ Yes, and equipment/assistance available

Risk of >500ml blood loss (7ml/kg in children)?
☐ No
☐ Yes, and two IVs/central access and fluids planned

Before skin incision

(with nurse, anaesthetist and surgeon)

☐ **Confirm all team members have introduced themselves by name and role.**

☐ **Confirm the patient's name, procedure, and where the incision will be made.**

Has antibiotic prophylaxis been given within the last 60 minutes?
☐ Yes
☐ Not applicable

Anticipated Critical Events

To Surgeon:
☐ What are the critical or non-routine steps?
☐ How long will the case take?
☐ What is the anticipated blood loss?

To Anaesthetist:
☐ Are there any patient-specific concerns?

To Nursing Team:
☐ Has sterility (including indicator results) been confirmed?
☐ Are there equipment issues or any concerns?

Is essential imaging displayed?
☐ Yes
☐ Not applicable

Before patient leaves operating room

(with nurse, anaesthetist and surgeon)

Nurse Verbally Confirms:
☐ The name of the procedure
☐ Completion of instrument, sponge and needle counts
☐ Specimen labelling (read specimen labels aloud, including patient name)
☐ Whether there are any equipment problems to be addressed

To Surgeon, Anaesthetist and Nurse:
☐ What are the key concerns for recovery and management of this patient?

This checklist is not intended to be comprehensive. Additions and modifications to fit local practice are encouraged.

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17.4 WHO surgical safety checklist. (Reprinted from World Health Organization Surgical Safety Checklist with permission. Available from: https://www.who.int/teams/integrated-health-services/patient-safety/research/safe-surgery/tool-and-resources.) ⏎

sequential compression device is superior to anti-embolism stockings. While preoperative marking of safe stomal sites is ideally done in multiple patient positions (lying, standing, etc.) and, therefore, before the patient is on the table, in an emergency setting it should still be considered at this point.

Remember to instruct the nurses on what non-routine instruments may be necessary (intestinal stapling devices, ostomy bags, meshes, sutures, etc.). Once the anaesthesiologist gives the go ahead for abdominal prepping, remember urinary catheterisation and nasogastric tube placement. It is wise to have the urinary collecting system in a location that can be monitored easily by the anaesthesia team and emptied by the operating theatre floor nurse. Position the overhead lights optimally and consider shaving or clipping hair from the surgical site, as excessive hair may cause pain by adhering to dressings after surgery. If possible, rapidly review the results and imaging, and have them readily available prior to scrubbing.

In patients with unstable bleeding, most of these steps may have to be skipped in favour of rapid intra-abdominal vascular control. Surgical skin preparation solution is poured or rapidly painted over the abdomen, minimal drapes are applied and the abdomen is entered to compress or clamp bleeding. Other preparations will have to be addressed by assistants on the OR floor as needed.

For all other patients, emergency laparotomies, and laparoscopies, require skin preparation of the abdomen from a few centimetres above the xiphisternum to the pubis craniocaudally. Remember to prepare to at least a point beyond both midaxillary lines to facilitate dependent and sterile drain sitting, if needed. There are no clear recommendations for disposable or reusable surgical drapes.

The 'surgical pause'

An additional layer of safety can be added in most patients just prior to incision, wherein additional information is checked one more time. Apart from patient and procedure details, a few things to consider here are questions such as whether there is adequate blood for transfusion available; if postoperative care is planned in the ICU with an available bed; and if medications such as antibiotics, antiepileptics and steroids (if indicated) have been administered. It is also important that the nursing team has established a baseline 'count' of instruments and sponges at this point.

EMERGENCY LAPAROTOMY

Emergency laparotomy remains the standard approach for all patients with an unstable surgical abdomen and is often the best procedure for most stable patients with generalised conditions. The ability to perform an independent exploratory laparotomy is a benchmark of general surgical training and is essential for an emergency surgeon's practice. While an optimal emergency laparotomy requires some ability to adapt to unplanned situations, and modify techniques, based on expertise and logistics, the essential pathway remains standard and is discussed below.

Access

A vertical midline incision is the simplest and most versatile choice when trying to access the abdomen. The tissues in the area are relatively avascular and therefore access can be expedient. When treating an unstable haemorrhaging patient, the 'three stroke' approach allows rapid access. This involves three cold cuts through the tissues: the first is with a scalpel through the skin, the second stroke is to the level of the fascia and the third, which is easier done by a heavy scissor, involves opening the fascia and peritoneum. The incision length must be generous enough to exteriorise contents rapidly and allow access to all areas. This rapid approach must be reserved for patients who have significant haemoperitoneum – the blood tending to prevent injury to underlying bowel, as injury to underlying bowel is a major concern. Nevertheless, when there is a need for rapid vascular control, any bowel injury must be addressed after control of the haemorrhage.

In all other patients, midline access is most easily achieved at the level of the umbilicus with an electrosurgical cautery unit. Preoperative diagnosis helps guide the decision on which side of the umbilicus to curve the skin incision – generally to the opposite side of the most likely stomal site. Some surgeons may even choose to incise straight through the umbilicus. After a scalpel is used to incise the skin, an electrosurgical cautery can be used to dissect tissues to the fascia. Entry through the fascia is done by opening only the fascia and then lifting the underlying peritoneum between clamps for a precise incision by scalpel or scissors and then abdominal entry. Cultures should be collected from any fluid encountered at this point. Also remember to communicate with the anaesthesia team at this point, as there are significant haemodynamic concerns during decompression of a tense abdomen. Further extension of the incision can be guided by the contents encountered at entry into the peritoneum. Frank bile may suggest a peptic ulcer perforation, while foul-smelling feculent content could represent a perforated gangrenous appendicitis. In any case, the vertical midline entry can easily be extended in either direction, depending on the results of the next phase of the surgery (see the next section on 'Assess').

Of note here are situations where either the midline is scarred or there are hernias. It is generally advisable to enter the fascia through a point that is free of previous surgical scars. This is because adhesions to a previous scar are likely, and an inadvertent bowel injury will only complicate an already emergent, and therefore non-ideal, situation. The presence of midline hernias (incisional or otherwise) must be noted prior to incision. If the hernia is the indication for an emergency operation (due to obstruction or strangulation), the hernial sac must be dissected and opened and the underlying bowel assessed. When there is perforation into the hernial sac, it may be appropriate to try and control the contamination prior to entry into the true abdomen. This is also recommended when dealing with non-midline hernias with strangulation or perforation. If the indication for the laparotomy is unrelated to the hernia, care must be taken not to injure structures adherent to the sac. Smaller incisional, or umbilical, hernias that are asymptomatic but just happen to be in the path of the incision must be reduced, any adhesions to the sac must be released to allow exploration to continue and the fascia must be closed routinely during the closure of the midline wound. Considerations on using prosthetic meshes are discussed below.

Assess

Once entry is established, most patients having an emergency laparotomy require a thorough abdominal exploration. Even an obvious preoperative or evident intraoperative diagnosis may be associated with a second pathology. The stomach and duodenum must be assessed for integrity and the position of the Ryle's tube. The small bowel must be examined from the duodenojejunal flexure to the ileocaecal junction, and the large bowel inspected and palpated. The number of visceral perforations and/or the length and degree of ischaemia must be documented. Pelvic structures, such as the bladder, uterus and ovaries, can be assessed at this point. Remember to also examine the gallbladder, hepatic surface and spleen. Finally, consider opening the lesser sac, especially when there is no preoperative CT scan and if there are any concerns about posterior gastric perforation, pancreatic injury or collections in the lesser sac. The duodenum may have to be 'Kocherised' to address the possibility of posterior perforation or injury, especially when there are extensive peritoneal signs in Morrison's pouch and no other cause is found.

It is also important to assess the patient's physiology at this point, as these parameters play a much larger role in further surgical decision-making in emergency surgery than in elective settings. It is important to obtain information from the anaesthetic team, such as the patient's haemodynamics (including the inotropic requirement and ventilatory concerns), the patient's temperature and the results of any new tests (e.g. blood gas analyses or viscoelastic assays). These parameters must be taken into account with the surgical findings in planning and performing next steps.

Action

The final stage of the laparotomy is determined by what is found surgically and, as mentioned above, by the patient's physiology. A surgeon should consider damage control concepts at this point, even in non-trauma settings.

The primary actions required largely follow the previously outlined concepts of the primary indications for the surgery itself. Bleeding and peritoneal sepsis are addressed. Haemorrhage control depends on the site and type of haemorrhage and may involve ligature, stapling, vascular repair, cauterisation or even packing.

When dealing with peritoneal infection from perforation or an abscess, it is important to suction out pus, lavage gross debris and then mop the area dry. Overzealous lavage can lead to hypothermia if the saline isn't warm enough and may even lead to interloop collections if not drained adequately prior to closure.

Surgery for overt perforation will depend on the organ involved, its location and the patient's physiology. Always consider taking a sample of the perforated edge in an emergency setting, especially when diagnosis is in doubt. Peptic ulcer perforations can be repaired with an omental patch or an inflamed appendix or the gallbladder should be excised and most other perforated bowel either resected or repaired as indicated (see relevant chapters). If the perforation is secondary to a downstream obstruction, then the obstruction must be addressed as well and, if the obstructing lesion cannot be safely removed, a proximal defunctioning stoma must be considered. If the primary pathology is malignant, or possibly malignant, consider the fact that emergency resection may not be optimal in terms of oncological clearance – it may be more appropriate to defunction an obstruction with an appropriately sited defunctioning stoma as opposed to attempting a complex, extensive resection. This decision is also influenced by the surgeon's expertise in the diseased organs. In addition, if there is a very high level of obstruction (in the duodenum or jejunum) due to unresectable pathology, the situation may be alleviated by an internal bypass.

In patients with established intestinal ischaemia, all involved bowel must be resected. When this is secondary to an internal twist, or herniation, care must be taken to resect the bowel prior to re-establishing vascular flow to avoid reperfusion of toxins from the ischaemic segment into the systemic circulation. Additionally, if the pathology causing the ischaemia is an ongoing process, an open abdomen type procedure may be considered wherein the ischaemic segment is resected, the ends stapled or closed, and the abdomen closed temporarily with a repeat laparotomy at 24 to 48 hours. This allows for physiological recovery and determination of any further ischaemia before a definitive procedure can be performed. In many centres, it may also be prudent to consider closing the abdomen without resection when ischaemia is extensive and there is no access to bowel transplantation.

In patients in whom an obstructive pathology has not yet caused a perforation, surgery proceeds for the underlying cause. If the obstruction is secondary to adhesions, releasing the adhesive band usually resolves the situation. However, tumours or strictures may require resection, a diversion stoma or even an internal bypass, depending on the site of the lesion. Occasionally, massive obstruction of the bowel may prevent access to the pathological site despite an extensive laparotomy. In these circumstances, if an enterotomy is considered, care should be taken that an enterotomy is performed at a site that can be either brought out as a stoma or easily repaired. Every attempt should be made to prevent spillage. It is always important to check for any distal pathology downstream, after releasing the obstruction site, especially if a diversion stoma is not planned.

Some specific considerations in emergency surgery are discussed below.

Intestinal anastomoses in emergency surgery

Whether or not to anastomose is a frequent cause of concern, and debate, in emergency surgery. The primary concern after every anastomosis is whether the patient will have an anastomotic leak or a complication with significant morbidity and risk of mortality. While the general recommendation is to perform a stoma when there is doubt, patients with stomas often have a lower quality of life and require further surgical care for closure (if possible). Some contraindications for anastomosis include, but are not limited to, severe sepsis, hypoalbuminaemia, peritoneal malignant deposits and faecal contamination. Some of these patients may be tackled at centres with aggressive perioperative care and careful monitoring, and a 'high risk' anastomosis can be performed. However, if there are multiple contraindications, anastomosis is not advisable. The site of the anastomosis is also important, with a much lower risk of a clinically significant leak in small bowel and gastric suture lines as opposed to colonic anastomoses. If there is doubtful bowel viability, however, anastomosis is absolutely contraindicated, and a stoma must be considered. If a stoma is not feasible in the primary surgery, sepsis is controlled, and a staged approach must be planned with a re-look laparotomy.

It is important to note that the patient's physiology also determines the safety of an anastomosis. A patient on multiple inotropic support, who is hypothermic and severely acidotic, is likely to leak if an anastomosis is performed.

When an anastomosis is considered a safe option, the principles of the surgical procedure largely remain the same. While stapled anastomosis may be preferable in terms of reduction in operating time, some surgeons prefer hand-sewn techniques in oedematous bowel loops. There is no clear evidence in emergency surgery of the advantages of stapling over a hand-sewn anastomosis, and the choice depends on the surgeon's expertise and other considerations such as cost and/or availability of devices. However, having skills in hand-sewn anastomosis is a prerequisite, even when using stapled devices, as there are always chances of technical failure.

Drains in emergency abdominal surgery The routine use of intra-abdominal drains in clean, or clean contaminated, emergency laparotomies is discouraged with a low level of evidence. Drains do not prevent intra-abdominal sepsis and may lead to unnecessary complications. Suspicion of intra-abdominal sepsis is better confirmed with a combination of clinical, biochemical and radiological assessments.

However, the use of drains in patients with gross contamination is less clear and largely still advocated. Dependent areas in these patients are likely to collect pockets of pus that may be alleviated by the placement of drains for the first few postoperative days. Additionally, certain traumatic conditions, such as biliopancreatic injuries, may require long-term drain placement.

Fascial closure after emergency abdominal surgery Fascial closure post emergency laparotomy requires several considerations not applicable to elective surgery. The first thing to consider is whether the patient is planned for early re-exploration. In this situation, closure is avoided all together or is by a temporary measure. If a definitive closure is planned, there is still some debate on whether interrupted suture closure is better than continuous suture closure.

A key aspect in abdominal closure is the patient's ventilatory physiology. In situations where there is significant bowel oedema, and abdominal closure seems tight, it is important to communicate with the anaesthesia team about worsening ventilatory pressures (or volumes, depending on the device setting) during fascial closure. While some decompression may be obtained by emptying bowel contents through the Ryle's tube, or an enterotomy, it must be remembered that these manoeuvres carry a risk of bacteraemia. Difficulty in ventilating a patient at this stage should raise the concern of worsening intra-abdominal hypertension leading to postoperative abdominal compartment syndrome. It is prudent, therefore, to consider alternative methods, such as an absorbable polyglactin mesh laparostomy, a 'Bogota bag' or a skin-only closure as a temporary measure (Chapter 6).

Changing gloves and instruments during fascial closure has been shown to result in lower infection rates in a large multicentre, multinational cluster randomised trial and should be considered for all emergency abdominal laparotomies.

In contaminated cases, a delayed closure of the skin should be considered to reduce surgical site infection.

Use of non-absorbable meshes after emergency surgery The current recommendations for the use of prosthesis in clean, and clean contaminated, operations remain the same for patients undergoing elective or emergency hernia repair. Primary repair is reserved for the smallest of defects and a non-absorbable mesh may be used in all other cases with adequate antibiotic cover. Most of the data for these recommendations come from elective settings.

In patients with contaminated interventions, which is far more likely in emergency settings, the recommendations are to use a biological mesh, where feasible and if available, if primary repair is not possible. However, biological meshes are not widely available and are expensive. Some surgeons may choose to address these defects with a non-absorbable mesh (e.g. a polypropylene mesh), although the risks of infection and subsequent incisional hernia are high. In an emergency setting, the most viable option available may be to perform a controlled ventral hernia with an absorbable mesh or 'skin-only' closure. This approach is safer than a forced closure causing abdominal hypertension and may be superior to a likely non-absorbable mesh infection.

EMERGENCY LAPAROSCOPY

The advent of laparoscopy and minimal-access surgery has greatly improved the care of elective surgical patients in many ways. In emergency settings, laparoscopic approaches are standard in stable patients with appendicitis, certain gynaecological conditions (see Chapter 26) and cholecystitis and are increasingly popular in patients with peptic ulcer perforation. Many centres now advocate emergency laparoscopy in most stable patients, as surgeons become increasingly confident in minimal-access approaches and technological advancements allow better instruments and devices. The primary advantage of laparoscopy remains earlier recovery and, therefore, greater acceptance by most patients in most settings, and a 'laparoscopy-first' approach is now recommended in stable patients. However, it must be remembered that laparoscopy has significant disadvantages in certain situations, may be an inferior choice for definitive treatment of certain conditions, and laparoscopic expertise and equipment may not be available.

Emergency laparoscopy proceeds in the same three phases as laparotomy.

Access

An open Hasson's technique is preferred in most emergency situations, especially when there are concerns about intestinal dilatation. A closed Veress needle technique can be considered in the absence of abdominal distention and when there is an abnormality, such as previous incisions, which preclude easy opening at the umbilicus. A fluid sample for culture should be taken if this may help in subsequent antibiotic sensitivity. Once entry to the abdominal cavity is established and visually confirmed after insertion of the camera, further ports are inserted under direct vision, depending on the pathology and need for further ports. Communication with the anaesthesiologist regarding the patient's ventilation during insufflation is crucial, as the increased abdominal pressures can cause significant concerns.

Assess

Once safe entry has been completed, assessment of the abdomen continues in a systematic manner like in an emergency laparotomy. All areas are sequentially assessed and pathologies noted. Having a preoperative diagnosis helps guide assessment and, if the diagnosis is confirmed, surgery proceeds directly as needed. When there is gross contamination, all debris is suctioned out and the area lavaged with copious irrigation.

Securing the patient with straps to the table, prior to surgery, facilitates diagnostic laparoscopic bowel examination, as the patient may be positioned to allow gravitational assistance. When an obvious pathology is not identified upon abdominal entry, viscera are examined methodically, like in open surgery. If assessment is not feasible for any technical or anatomical reason, conversion to open surgery should proceed without hesitation.

Action

The first consideration to be made during this phase is whether the procedure can be completed laparoscopically with the available equipment and expertise. Prolonged surgery or inadvertent injury due to overenthusiasm must be avoided in favour of what is safer for the patient. It is important in emergency laparoscopy that the scrub nurse and floor staff are prepared for the higher need for a rapid conversion to open surgery than in elective surgery.

Additionally, a laparoscopic-assisted procedure may provide a happy medium; for example, a perforation can easily be exteriorised through a much smaller incision, while a good lavage can be completed laparoscopically.

If laparoscopy is considered the best approach, the surgery proceeds as indicated for the underlying organ. The principles on anastomoses, stomas and drains are the same as for open surgeries.

POSTOPERATIVE CARE IN THE OPERATING ROOM

Surgery does not end with skin closure. It is imperative that a competent member of the surgical team remains with the patient during the immediate postoperative period, which includes reversal of anaesthesia, extubation and transfer from the operating table to the recovery area or ICU. As mentioned earlier, we recommend that the surgeon completes their notes at this point. The patient's drains and catheters must be secured and labelled as needed. The postoperative plan and orders must be documented, and any samples must be correctly labelled for testing and analysis. Precise instructions on antibiotics, nutrition and specific postoperative monitoring should be documented.

The surgeon should talk to the patient's caretakers, if they are available, to update them on the situation. This communication is especially important in emergency surgery, as this may be the first time the surgeon interacts with the patient's family. In addition, morbidity and morbidity risks are high, and communication is important to reduce complaints and dissatisfaction, especially when outcomes are suboptimal.

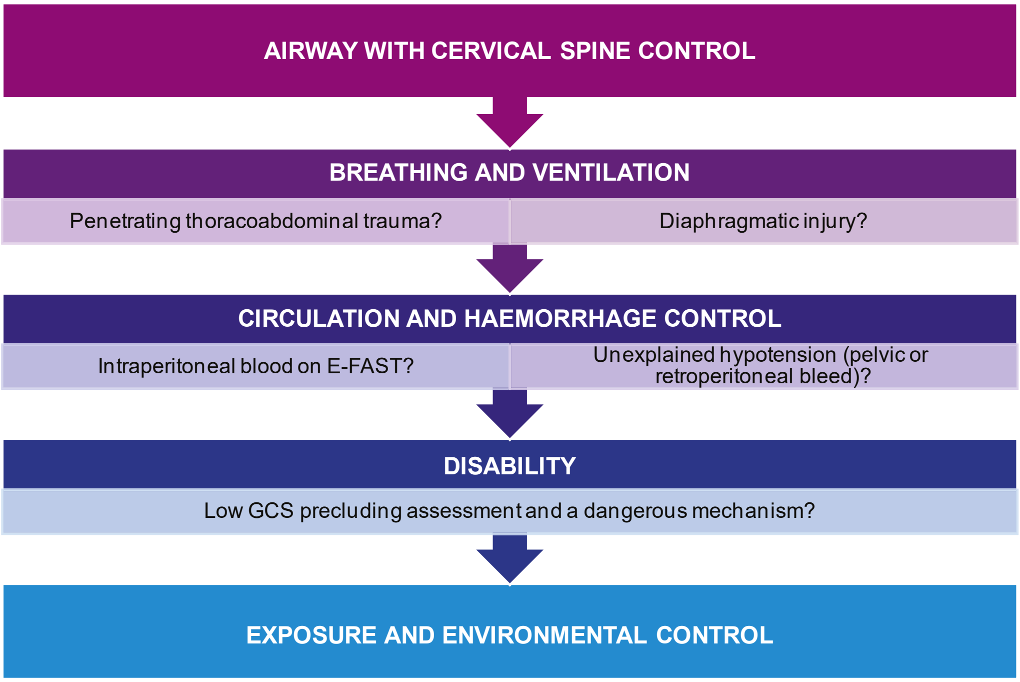
CONCEPTS IN THE MANAGEMENT OF ABDOMINAL TRAUMA

The American College of Surgeons' ATLS course provides a systematic approach to the management of patients with traumatic injuries (Figure 17.5). It has been demonstrated that the trauma care providers' organisational and priority skills improve significantly, and for several years, after having taken this course. Trauma is a highly time-sensitive disease and benefits from these attributes. We recommend these principles as a baseline prerequisite for the effective and safe management of patients with abdominal trauma, and all further discussion in this section assumes that these principles are followed.

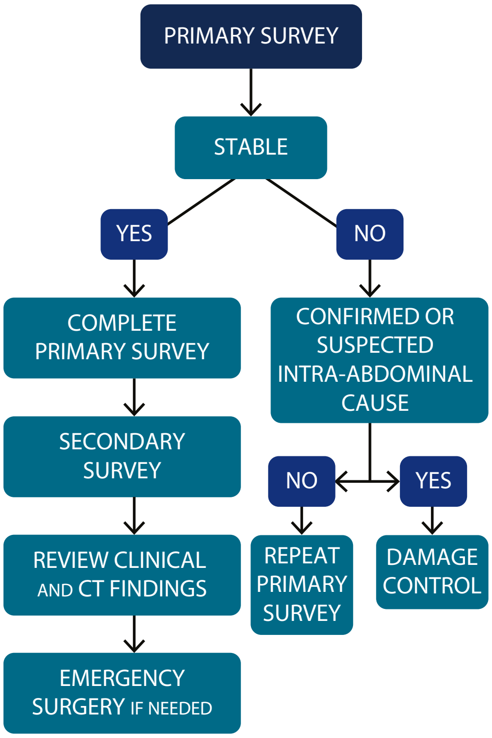
Trauma to the abdomen may arise from blunt, penetrating or mixed mechanisms (e.g. blast injuries). While the mechanism of injury helps predict the pattern of injuries and possible associated injuries, the primary decisions in surgical management of trauma are dictated by the patient's physiology. When performing a 'primary survey' following ATLS concepts (Figure 17.6), abdominal trauma is first noted during the assessment of 'circulation and haemorrhage control'. Therefore, an active intra-abdominal bleed that does not respond to resuscitation will require haemorrhage control by surgical intervention, and the following steps are carried out only after control is established. Alternatively, intra-abdominal injuries such as an isolated hollow viscus perforation found during the 'secondary survey' also require surgery, albeit with less urgency. Unstable patients with obvious abdominal trauma (and occasionally even the suspicion thereof) require an urgent 'crash laparotomy' with damage control principles. Meanwhile, all stable patients benefit from appropriate evaluation (which in most scenarios will involve a contrast-enhanced CT scan, if available). The presence of patient stability does allow different approaches to the management of some trauma situations depending on local resources and expertise (varying from minimally invasive methods to radiological interventions and even non-operative policies). A detailed discussion on the subtleties of management of each abdominal organ is beyond the scope of this section, but a general guide to the concepts used in surgery for abdominal trauma is discussed in the next section.

SURGERY FOR UNSTABLE PATIENTS WITH ABDOMINAL TRAUMA

After airway, cervical spine control, breathing and ventilation are assessed and appropriately managed, as stated earlier, major abdominal trauma is usually noticed during management of the circulation. The


AIRWAY WITH CERVICAL SPINE CONTROL
BREATHING AND VENTILATION
Penetrating thoracoabdominal trauma?
Diaphragmatic injury?
CIRCULATION AND HAEMORRHAGE CONTROL
Intraperitoneal blood on E-FAST?
Unexplained hypotension (pelvic or retroperitoneal bleed)?
DISABILITY
Low GCS precluding assessment and a dangerous mechanism?
EXPOSURE AND ENVIRONMENTAL CONTROL

17.5 Vertical resuscitation in trauma – points where intra-abdominal injury should be suspected are noted. E-FAST, extended focused assessment with sonography in trauma. GCS, Glasgow Coma Scale. ⏎



17.6 Algorithm for the management of abdominal trauma. ⏎

first step here is to recognise the presence of shock, followed by simultaneous treatment and evaluation for the cause of the shock, which in trauma patients is due to haemorrhage until proven otherwise. A (extended) focused assessment with sonography in trauma ([E]-FAST) scan helps recognise intra-abdominal bleeding, while simultaneous resuscitation is started through at least two large-bore intravenous lines. The patient's response to this resuscitation (1 L of crystalloid and one unit of O-negative whole blood) classifies them into one of three categories:

1. *Non-responders* – patients who do not show improvement of vital signs
2. *Responders* – patients whose vital signs improve and normalise
3. *Transient responders* – patients who have a transient response that later deteriorates

The decision-making in non-responders with evidence of intra-abdominal haemorrhage is clear in that they need immediate surgical source control with simultaneous massive transfusion. Patients with major trauma who are responders need close monitoring, as they may deteriorate (and therefore become a transient responder). Such patients then follow the same management pathway as a non-responder, although, if contrast-enhanced CT (where available) has been completed, there may be additional information for surgical decision-making. Surgical steps for these two types of 'crashing' patients are discussed below.

Use of blood and medical haemostatics in trauma

Effective management of massive abdominal trauma needs a functioning blood transfusion centre with pre-existing contingencies, not only for the storage of blood and blood products, but also for their rapid and safe transport to the various areas of the hospital where these patients are treated (generally the ED, the OR and the ICU). The current understanding of the pathophysiology of the acute coagulopathy of trauma justifies the usage of blood, plasma and platelets in a 1:1:1 ratio once massive haemorrhage is recognised. The Assessment of Blood Consumption (ABC) score is a validated tool that helps predict the need for activation of this protocol upon arrival to the ED. It includes:

- Penetrating mechanism of injury
- A positive FAST
- A systolic blood pressure of 90 mmHg or less
- A heart rate of 120 beats per minute or greater

The presence of any two of the above can be used to initiate such a massive transfusion. Additionally, there is evidence to justify the use of tranexamic acid when patients present within 3 hours of injury. Other considerations include the need for reversal of medication-related anticoagulation (e.g. warfarin), if applicable. Finally, the usage of point-of-care viscoelastic assays is increasingly standard in the treatment of trauma patients and allows for targeted parameter-directed product usage.

The non-availability of such resources should direct early transfer of most patients to centres that do have these facilities in place. Auto-transfusion of clean, uncontaminated blood, if available, is technically better than no transfusion at all but is not always pragmatic. It should, however, be considered by surgeons practising, or preparing to practise, in resource-poor settings. While the care of trauma in these areas is challenging, if the inability to transfer the patient is likely to lead to no intervention, a pre-existing plan and optimal resource utilisation are paramount.

The 'crash laparotomy' for trauma

Non-responders or deteriorating transient responder patients are in haemorrhagic shock from active bleeding. All efforts should focus on achieving an arrest of this ongoing haemorrhage, and no manoeuvre or testing helps these patients as much as surgical control. However, ATLS principles rightly insist on airway establishment, cervical spine control and decompression of the thorax by chest drainage (if indicated) taking precedence, as not addressing these concerns adequately is more rapidly lethal than circulatory collapse. Thankfully, these interventions are all rapidly achievable in experienced hands. Additionally, in resource-rich centres, trauma teams perform horizontal primary surveys addressing all five components simultaneously while maintaining the traditional vertical priority. The diagnosis of a non-responder status is ideally achieved in a matter of minutes, and a massive transfusion protocol is activated, as outlined below. At this point, the patient must be rapidly moved to the operating table. This section addresses the steps of surgery in patients with abdominal trauma who have reached this point in their care.

Preparation in the operating room A trauma OR is ideally in a state of constant preparation. Necessary equipment for surgery and anaesthesia are already ready for immediate deployment in the OR and no further preparation should be needed. In an ideal situation, the patient arrives with a scrub nurse already prepped. The cruciform position is ideal here, with the body supine and the arms abducted at 90°. This allows the surgeon to begin skin preparation (from above the nipples to the groin) and a full abdominal incision, while the anaesthesia team has access to the upper limbs and airway. Additionally, a resuscitative thoracotomy, if required, may also be performed (although general surgeons without formal trauma training may not be competent in resuscitative thoracotomy).

Unlike the extensive preparation described in the previous section, and if the surgical team has brought the patient to the theatre themselves, the surgeon only needs to note a few details at this point:

- The pH, the temperature and clinical or viscoelastic diagnosis of acute traumatic coagulopathy (components of the 'triad of death')
- The patient's heart rate, rhythm and blood pressure (the patient's haemodynamic status)

Surgical steps Unlike a routine emergency laparotomy sequence (access then assess then action), a crash laparotomy involves the following sequence:

1. Access
2. Bleeding control
3. Confirmation
4. Decision

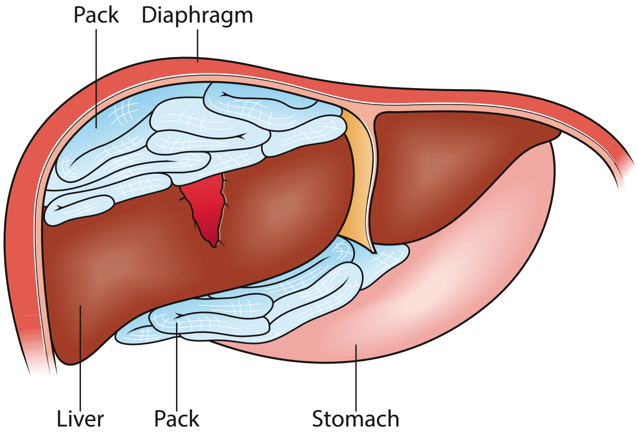
This 'ABCD' sequence holds true for all organs and mechanisms in abdominal trauma. 'Access' starts with a cold 'three stroke' incision as already described in the previous section. The length of this incision is from the xiphisternum to the pubis. While the cutaneous vasoconstriction from the haemorrhagic shock allows for this rapid cold incision, care must be taken to avoid common iatrogenic injuries to the left lobe of the liver, bowel and bladder. Rapid removal of blood and peritoneal contents and exteriorisation of the bowel is then performed to allow the next steps.

'Bleeding control' in this acute situation is often temporary and proceeds in one of two ways. In penetrating trauma, the general recommendation is to focus on the suspected tract and underlying injured vasculature. In blunt trauma, 'sequential' empiric abdominal region packing is preferred (also advocated in penetrating trauma by some surgeons). The exact order of the sequence is not as important as being systematic and not missing any injury.

Some patients who are rapidly exsanguinating will require rapid supracoeliac control of the aorta. This is done by dividing the relatively avascular gastrohepatic ligament and controlling the aorta at its entry into the abdomen. The stomach and oesophagus are reflected to the left and the diaphragmatic crura are divided if needed. Once the aorta is isolated, it may be compressed against the vertebra manually or controlled with an umbilical tape. This approach may be preferrable for general surgeons uncomfortable with operating in the thorax. However, in experienced centres, trauma surgeons may choose to achieve this via a resuscitative thoracotomy incision, as it is faster and allows for internal cardiac massage in a patient who is likely to have a circulatory arrest.

The next step, labelled 'confirmation' (for the sake of the alphabetical mnemonic), is akin to the 'assess' phase described in the earlier section. The main difference is that serial actions are taken to achieve definitive haemorrhage control and temporary sepsis control as each pack is sequentially removed. This may involve direct vascular repair, excision of the organ (e.g. splenectomy or nephrectomy), repacking (in major hepatic trauma) and rapid stapling of open hollow viscera.

In hepatic trauma, at this stage a Pringle manoeuvre (non-crushing occlusion of the gastrohepatic ligament) helps differentiate the source of bleeding (bleeding stops or reduces dramatically if the source is from the hepatic arteries or portal vein, provided there is no aberrant vasculature, but continues if the source is from the retrohepatic veins or inferior vena cava). Attempting advanced liver resection or repair techniques at this point carries high mortality, even in specialised liver surgery centres, and it is far more important to learn the technique to pack the liver appropriately. Essentially, hepatic packing should not compress the underlying vena cava and consequently drop the cardiac venous return (Figure 17.7). A sandwich or clockwise method is employed to attempt to restore liver anatomy and, crucially, no packs are inserted into any breach in the liver surface. An additional armament here is to 'plug' any hepatic arterial bleeding (by direct repair if it is a major hepatic artery visualised during surgery) or via angioembolisation in the next phase of treatment. Inflating a Foley catheter



17.7 Hepatic packing – the liver is sandwiched tightly between large pads. ⏎

into a penetrating trauma tract within the liver has also been described.

In most settings, renal and splenic trauma leading to instability are best treated by organ resection. Most general surgeons will not be able to successfully achieve partial resections rapidly in these organs in haemodynamically unstable patients, and it is an accepted principle of trauma surgery to avoid the focus on function preservation, which may be appropriate in an elective setting but not in a shocked patient.

Mesenteric bleeds are addressed by suture ligation or vascular stapling. Retroperitoneal bleeds need careful assessment – a non-expanding haematoma is usually best left alone. However, an expanding haematoma, or continued or worsening haemodynamic signs in the absence of other injuries, requires direct intervention. Depending on the site of concern, a left or right medial visceral rotation (Cattell–Braasch [Figure 17.8] or Mattox manoeuvre [Figure 17.9]) may be indicated for adequate exposure and direct control. These visceral rotations are rapid and relatively easy, as incisions go through avascular planes.

Intra-abdominal bleeding from pelvic injuries may require ligation of both internal iliac arteries and preperitoneal packing (Figure 17.10). It is also important to reduce pelvic volume in a patient with a pelvic fracture; this may be best served by external fixation (if expertise is available) but, at the very least, a pelvic binder should be used. In an ideal situation, optimal management may be to proceed with angiographic embolisation or transfer the patient to a facility where angiography is available.

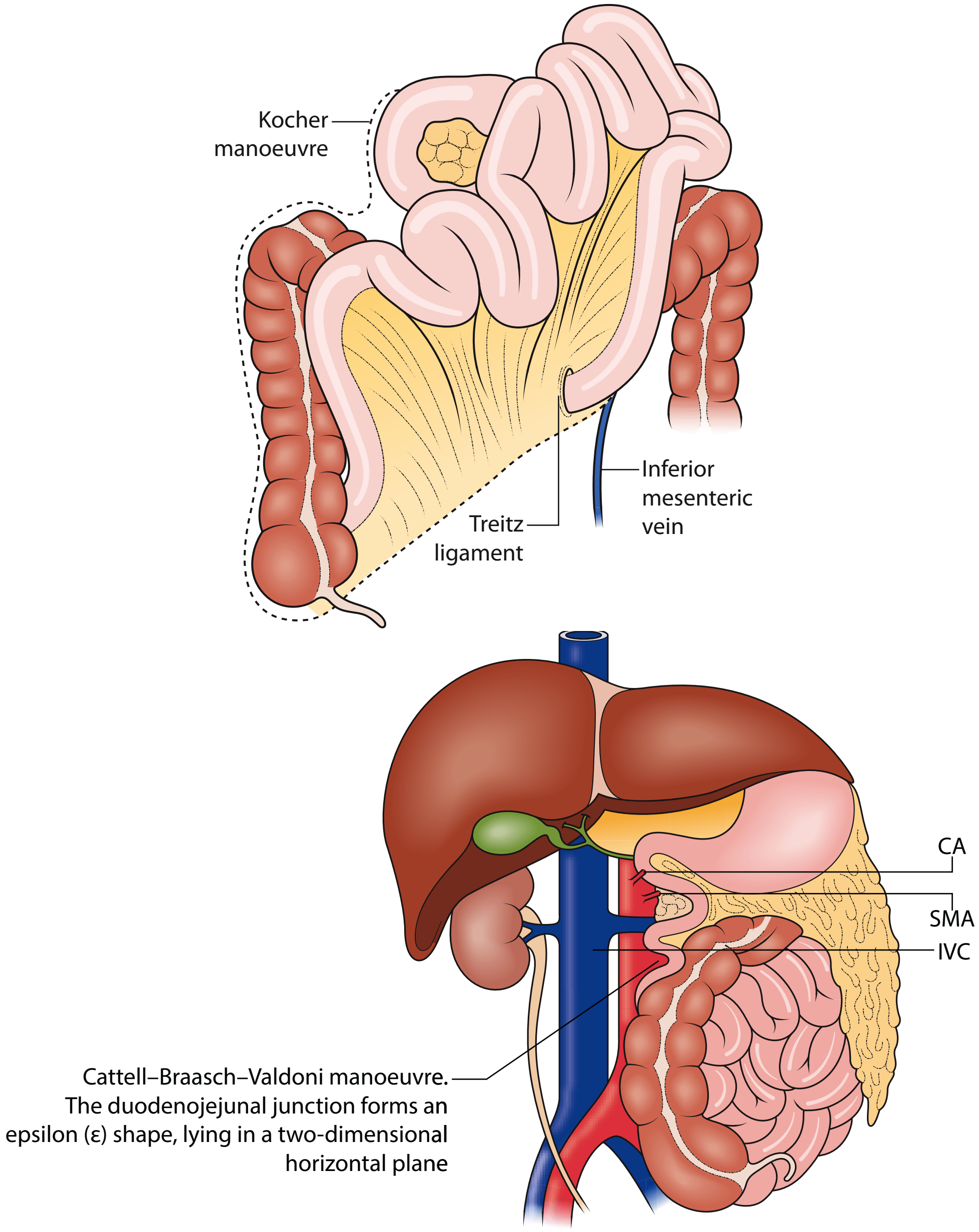
Finally, it is important to assess the lesser sac and remaining supracolic compartment. Pancreatic and retrogastric injuries can be rapidly assessed through the avascular left portion of the gastrocolic omentum. It is unwise to attempt major pancreatic resections in unstable patients, apart from a distal pancreatectomy (with a splenectomy) when there is clear transection of the body of the pancreas. Complex head-of-pancreas injuries are better dealt with temporarily by exclusion and drainage. Posterior gastric perforations can rapidly be controlled with running sutures in unstable patients. The diaphragm must also be assessed for minor injuries that can be repaired primarily. Major diaphragmatic lacerations are usually obvious upon entry due to the associated ventilatory disturbances. If there is a diaphragmatic injury, the thoracic cavity can be washed out through the defect, a chest drain is placed and the defect is repaired through the abdomen using non-absorbable sutures. It is also important to note hollow visceral injury due to the trauma itself, or due to iatrogenic injury from a chest drain when eviscerated abdominal contents in the thorax leads to misdiagnosis as a haemothorax or pneumothorax during the 'breathing' assessment in the ED. While such spillage into the thoracic cavity is ideally addressed by a thoracic exploration and washout, as transdiaphragmatic lavage is often inadequate, it may be best done at a second procedure as outlined below.

At this point, all open bowel should have been controlled using mechanical staplers or alternative methods such as continuous running sutures when staplers are not available. The next step is the 'decision' on whether to do any further surgery. It is rare for a truly 'crashing' patient to have reached a physiological state where complex repairs may be conducted at this point. Therefore, a decision on 'damage control' is often appropriate.

If definitive surgery is physiologically feasible, surgery for the affected organ, or organs, proceeds in the manner described in the previous section on emergency laparotomy. Additional procedures may also be considered; however, prolonged initial surgery in trauma patients is best avoided.

Post-surgical care Most patients who undergo crash laparotomies are still in the primary survey phase of their treatment. While an initial Glasgow Coma Scale assessment and pupillary reaction is likely to have been completed at this point in most centres, a formal assessment must be done at the end of resuscitation. Many patients may require completion of imaging (e.g. a whole-body CT, if indicated and available) and further surgical or angiographic intervention as indicated. It is also important to note that polytraumatised patients may also need other damage control or urgent interventions apart from abdominal surgery (e.g. vascular control of peripheral injuries, cleaning of open fractures or cranial decompression) and the emergency surgeon must facilitate these either simultaneously (for vascular control) or as soon as feasible (for neurosurgical interventions and open long-bone fractures).

It is also important to shift ongoing protocol-directed massive transfusions to parameter-directed

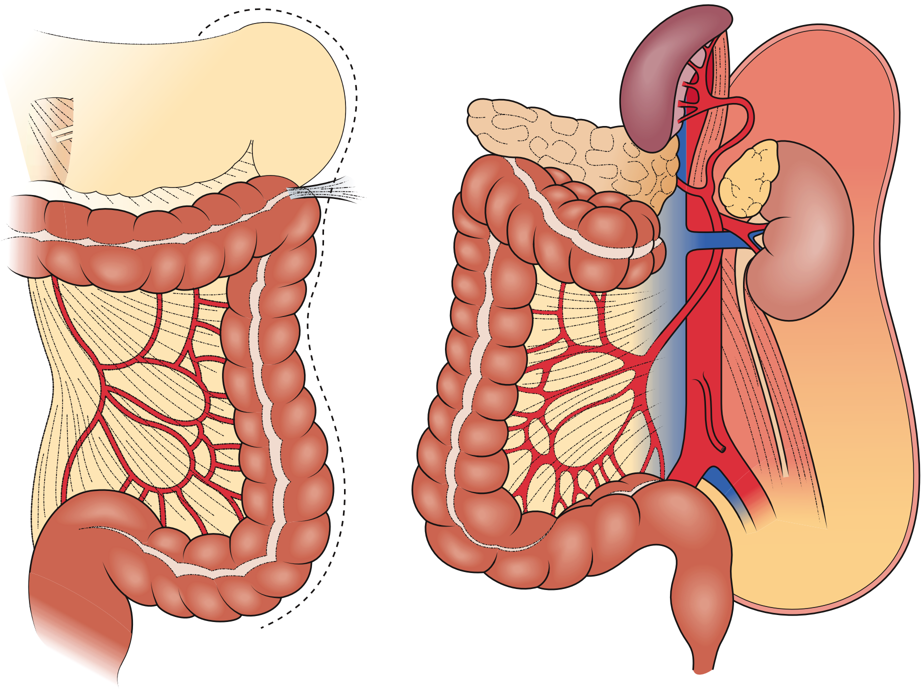

Kocher manoeuvre
Treitz ligament
Inferior mesenteric vein
CA
SMA
IVC
Cattell–Braasch–Valdoni manoeuvre. The duodenojejunal junction forms an epsilon (ε) shape, lying in a two-dimensional horizontal plane

17.8 The Cattell–Braasch manoeuvre. CA, coeliac artery; IVC, inferior vena cava; SMA, superior mesenteric artery. ⏎

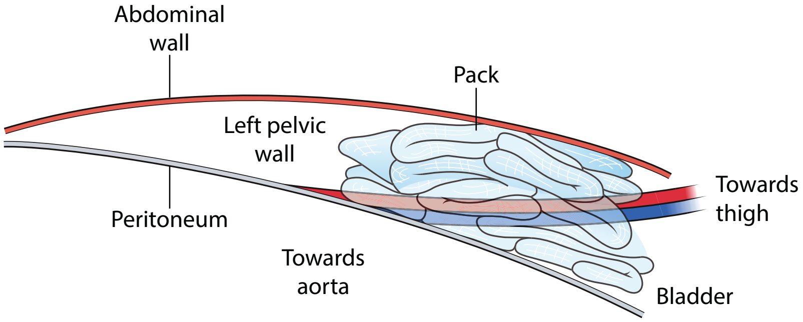
transfusion as early as feasible once haemorrhage control is achieved.

SURGERY FOR PATIENTS WITH STABLE ABDOMINAL TRAUMA

Most solid organ injuries are best managed expectantly, or with increasingly minimal interventions with advances in radiological and endoscopic interventions. However, hollow visceral injuries are a different situation. Patients with both penetrating and blunt injury mechanisms resulting in overt perforation peritonitis can be haemodynamically stable upon presentation to the ED. While it has already been stated that the presence of clinically overt peritonitis does not necessitate CT in the setting of an acute abdomen, stable patients with blunt abdominal trauma usually benefit from CT scanning. This is because haemoperitoneum from solid organ injuries can initially present with features similar to clinical peritonitis, and the management of those injuries is expectant, as opposed to emergency surgery. CT scans detect even minimal amounts of pneumoperitoneum – which would indicate an overt perforation and clearly justify the need for surgery, even in the presence of solid organ injury.



17.9 The Mattox manoeuvre. ⏎



17.10 Preperitoneal packing – once the pack is placed, peritoneal reflection is sutured to the anterior abdominal wall to ensure tamponade. ⏎

In these patients, the principles and steps of surgery are the same as for patients undergoing emergency surgery for non-traumatic conditions as outlined previously. In stable patients with penetrating trauma, decision-making may be tailored depending upon suspected velocity (projectile versus stab wounds), site of entry and likely internal trajectory. Previously, CT scanning was deferred in favour of formal exploration for anterior abdominal stab wounds that breached the peritoneum, and exploration was also advised for flank wounds that were suspected of tracking into the retroperitoneum. Trauma centres now uniformly prefer contrast-enhanced CT scanning for all stable patients with penetrating trauma. Upon suspicion of peritoneal breach on CT, a 'laparoscopy-first' approach has been advocated and, depending on the expertise and pattern of injury, the entire procedure can be safely completed laparoscopically. The presence of a large amount of blood in the abdomen, in the absence of an obvious cause, in penetrating or blunt trauma could be from a significant mesenteric tear and is an indication for a diagnostic laparoscopy. Alternatively, properly conducted serial physical examinations have been found to be a safe method in detecting clinical deterioration requiring surgery in both blunt and penetrating abdominal trauma.

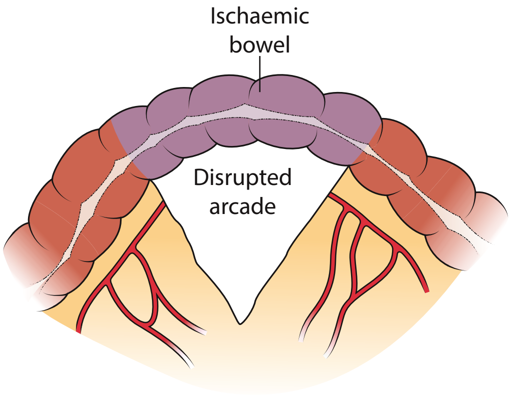
Additionally, some patients will benefit from a cystogram (for bladder injuries) or delayed phase contrast-enhanced CT imaging (which helps assess the grade of renal injury) when there is frank haematuria on urinary catheterisation, or from clinical or plain X-ray radiological evidence of pelvic fractures.

Haematuria or blood at the urinary meatus upon presentation to the ED is assessed by a retrograde urethrogram done prior to urinary catheterisation. While intraperitoneal rupture of the bladder will require surgical intervention, other lower urological injuries (e.g. urethral injuries) may benefit from urinary diversion procedures and specialist surgical repair. An extraperitoneal bladder injury can be managed expectantly, with an indwelling catheter left in place for 2–3 weeks. All renal injuries in stable patients are best addressed expectantly or with angiographic interventions, even with high-grade renal trauma.

Patients with injuries to the abdominal wall musculature also benefit from CT scanning. Penetrating trauma with evisceration and suspicion of contamination requires repair of the musculature, and assessment of internal structures may be completed through laparoscopy, if competencies exist, or even a laparotomy. Blunt abdominal injuries may also be associated with herniation of internal contents, which is not always easy to detect on clinical examination due to tenderness from the injury or other distracting injuries. Detection of these types of injuries on CT allows for appropriate planning of incisions, repair and exploration.

Laparoscopy in trauma

The most common indication for laparoscopy in trauma is the presence of haemoperitoneum on a CT scan that is not explained by solid organ injuries. Large ‘bucket handle’ mesenteric tears do not always compromise the bowel integrity or vascularity initially (Figure 17.11), and these patients may be stable on presentation or stabilise with primary survey. If unaddressed, the resulting ischaemia results in a delayed perforation and eventually can lead to septic shock. In some patients, the ischaemic segment strictures or adhesions form that lead to acute obstruction. Laparoscopy offers a minimally invasive method to assess these patients and can offer the advantage of a reduced incisional size, when expertise does not allow the completion of a resection endoscopically.



17.11 The ‘bucket handle’ tear. The bleeding from the mesenteric injury may cease without surgery, leading to a transient period of stability before secondary haemorrhage or perforation of the devascularised bowel. ⏎

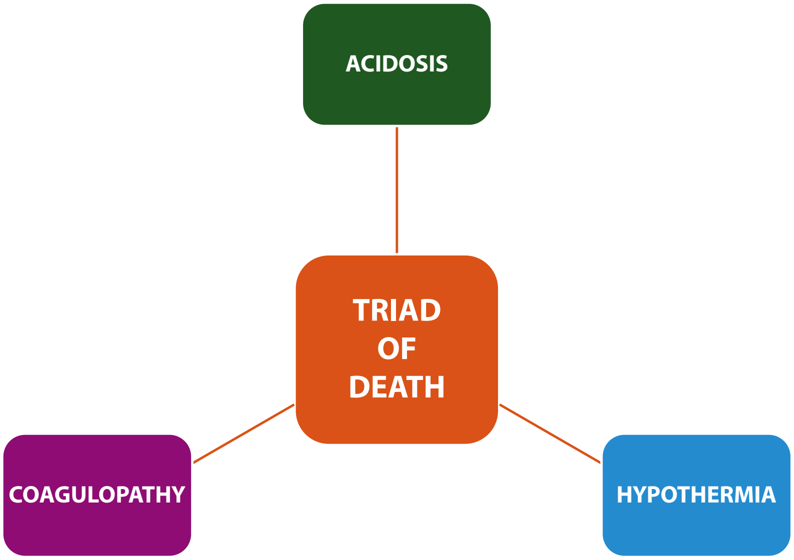
Diaphragmatic tears and intraperitoneal bladder injuries can also be repaired laparoscopically by highly skilled surgeons. Laparoscopic colonic diversion offers a minimally invasive option for patients who require diversion for perineal and lower urological injuries, especially in the absence of an intra-abdominal injury. Other indications include laparoscopic feeding gastrostomy, for patients in whom endoscopic or radiologically guided percutaneous procedures are not possible or when they are unavailable. Finally, biliary peritonitis from liver injuries that were initially addressed non-operatively may benefit from laparoscopic lavage and appropriate drain placement. These patients also benefit from specialist expertise, if available, as they may need a sphincterotomy and/or a biliary stent placement.

DAMAGE CONTROL FOR THE GENERAL SURGEON

The concept of ‘damage control’, a term originally borrowed from US Navy practices that help damaged ships stay afloat, arose from lessons learnt in the 1980s in US trauma centres. Victims presenting with multiple penetrating wounds from newly introduced 9 mm semi-automatic pistols underwent long definitive surgeries resulting in a completely repaired, but often lifeless, patient. Prolonged definitive intervention worsened the already massive physiological insult in these patients and led to the lethal triad of death: hypothermia, acidosis and coagulopathy (see Figure 17.12). Therefore, the primary lesson learnt was to prioritise physiological restoration over anatomical repair. This essentially entails four surgical steps:

1. Control bleeding
2. Control sepsis
3. Prevent further injury
4. Do nothing else

This is followed by intensive physiological correction over the next 24 hours, allowing patients to recover enough to undergo definitive repair. Intensive care specialists quickly adapted the ‘damage control surgery’ concept to ‘damage control resuscitation’ principles, focusing on the same priority of physiological restoration in the setting of traumatic haemorrhagic shock.



17.12 Lethal triad. ⏎

Initially described for abdominal injuries, these concepts have been extended to other injuries as well and are now also being applied increasingly to non-traumatic conditions, albeit with some modifications and varying degrees of success.

DAMAGE CONTROL FOR ABDOMINAL TRAUMA

The ideal time to commence a patient on this pathway is at the outset of care. There are five phases of care described, as outlined below.

Phase 0

Also called 'presurgery damage control', this phase involves the rapid triage and transport of the victim to the OR (or, in some cases, an interventional suite) from the site of trauma. The key concept here is to recognise the need for, and initiate, a balanced transfusion protocol (1:1:1 as outlined above) or whole blood. The initiation of a massive transfusion protocol represents an indication for damage control surgery in the next phase.

An important concept in phase 0 care is the use of permissive hypotension. This technique involves allowing the mean arterial pressure to remain below normal physiological levels in a patient with traumatic haemorrhage, to prevent further bleeding and increased oedema from crystalloid resuscitation. It is important to note that this limited threshold varies depending on a series of factors, which include previous history of hypertension or cardiovascular disease, mechanism of trauma (with poor evidence of efficacy in blunt trauma) and the concomitant presence of a traumatic brain injury (where cerebral perfusion requires higher thresholds). The complexities of successful execution of this technique in a low-resource or low-experience setting may limit its practical application to patients with isolated abdominal haemorrhage who are alert and remain responsive until anaesthetic induction in the OR.

Phase 1

The next phase starts in the OR with the initial principles explained in the section on 'crash laparotomy'. While there are no evidence-based guidelines on when to choose damage control as the 'decision' step, indications include:

- Massive physiological insult:
  - Hypothermia (<34°C)
  - Coagulopathy (evident clinically or based on laboratory values)
  - Shock and acidosis (pH <7.2, lactates >5 mmol/L or base deficit >8 mmol/L)
- Massive resuscitation (e.g. requirement of the initiation of a massive transfusion protocol or >10 blood products administered with ongoing requirements)

- Severe pattern of injury (including, but not limited to, complex pancreaticoduodenal injuries, severe liver trauma, difficult-to-access venous injuries and severe or combined injuries)
- Need for aortic occlusion, through either a resuscitative thoracotomy or a retrograde balloon vascular control (implies major physiological insult)
- Need for staged surgery (due to an inability to close the incision due to visceral oedema, concerns about abdominal compartment syndrome or the need to reassess bowel ischaemia after resuscitation)

Once this decision is made, the wound is temporarily closed and the patient is moved to the ICU for the next phase.

Phase 2

This involves continued balanced resuscitation measures to prevent worsening visceral oedema and to correct coagulation parameters. Viscoelastic coagulation assays, if available, are especially useful here as a guide to blood product usage. The patient is warmed and airway and ventilatory management continues until physiological recovery over the next 24 to 48 hours.

Phase 3

Definitive repair is carried out in this phase, the exact timing being dictated by the patient's physiological recovery. Not all repair needs to be done during one operation, and phase 3 may involve several stages and, if need be, several specialists. It is important to remember that some patients may have had damage control for multiple injuries. In general, vascular repairs are carried out, bowel injuries are anastomosed or exteriorised, temporary external fixators (e.g. for the pelvis) are internalised if possible and the abdomen is closed (again, only if possible). Abdominal surgery proceeds in a similar manner to what was described in the section on emergency laparotomy.

Phase 4

Phase 4 involves delayed soft tissue cover or reconstruction of defects as, and when, the patients' recovery allows.

DAMAGE CONTROL IN NON-TRAUMATIC EMERGENCY LAPAROTOMIES

Damage control surgery concepts emerged from the improved understanding of the pathophysiology behind acute traumatic coagulopathy and what effects medical interventions have on physiological responses in the setting of acute traumatic injuries. The physiology-based approach of damage control surgery has clear benefits in the treatment of trauma, and similar physiological concepts have been translated for use in non-traumatic conditions. While further research on the actual efficacy of using this concept is ongoing, there appears to be a reduction in the expected mortality rate. Nevertheless, the indications for damage control surgery have been expanded beyond the lethal triad to include factors such as the presence of perioperative septic shock, comorbid illness, age (>70 years) and male gender. Definitive indications here are still being debated, with a wide range of patient characteristics and generally sicker patients forming the damage control surgery arms of most retrospective analyses between damage control surgery and definitive procedures. While overutilisation of this technique does increase morbidity (from increased stay in the ICU, a prolonged open abdomen and/or multiple procedures), the reduction in mortality risk seems to justify this approach, even in a non-traumatic setting.

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18 Vascular surgical techniques: Vascular access and trauma

Nishant Kumar and Indrani Sen

INTRODUCTION AND EPIDEMIOLOGY

Vascular trauma has been an area of interest since ancient times; the earliest report of the ligature of a vessel for haemostasis is attributed to Celsus.[1] Techniques to control bleeding by compression, cold, elevation, hot iron and styptics prepared from lead, copper or vegetable matter were described in India, China, Europe and Egypt. In more recent times, Ambroise Paré described ligature for the control of arterial bleeding; however, clinical outcomes were poor, with high rates of amputation, infection and blowouts of the ligated artery. In the 1800s, the first attempts at arterial repair involved a veterinarian's stitch, suture material, invagination, clamps and the use of pins. The 1900s were marked by continued work from Murphy, Mattas, Carrell and many other surgeons. However, significant clinical advances in the repair and management of vascular injury are much more recent. Military vascular injury, notably following the Second World War and the Vietnam War, led to the development of many of the principles surrounding the management of vascular injury.[2,3] The importance of appropriate triage, the management of arterial and venous injuries, the management of soft tissue injuries, concomitant fractures and the role of tissue debridement were identified. Parallel improvements in vascular surgical techniques, the availability of endovascular technology, anaesthesia and pre-hospital resuscitation continue to improve outcomes following vascular trauma.

Vascular injury can be a result of blunt or penetrating trauma. The wall of an artery consists of three layers: the outermost layer, composed of connective tissue, is the tunica adventitia; the middle layer is the tunica media, composed of smooth muscle cells with varying proportions of elastic tissue, and this contributes the most to the thickness of the arterial wall; the innermost layer is the tunica intima, composed of a thin layer of endothelial cells supported on a basement membrane. Blunt arterial injury results in contusion of the arterial wall, and this shear injury can cause intimal tears and adventitial disruption, with resultant haemorrhage or thrombosis. Blunt injuries can occur from indirect trauma, such as from the distraction forces following long bone fractures and joint dislocation or with acceleration–deceleration injuries in traffic/motor vehicle accidents, strangulation or falls. These injuries cause contusion of the arterial wall, with shear forces leading to intimal tears and adventitial disruption, resulting in haemorrhage or thrombosis. Penetrating trauma results in partial, or complete, transection of a vessel by a sharp instrument such as a knife. Other modes of injury include falls, household trauma, work accidents, athletic injuries, violent crime and iatrogenic trauma.

A combination of both mechanisms (blunt and penetrating) may occur with firearm injuries, where the injuries are more complex. Here, additional thermal injury, high-velocity fragments and blast injury to local tissue may result in an additional area of intimal damage that is diffuse, or is more extensive, than the point of disruption. The epidemiology of vascular trauma is variable; in some countries, the predominant presentation may be secondary to traffic accidents causing blunt arterial injury.[4,5] In other areas, firearms, landmines, stab injuries, iatrogenic injuries, vascular injuries secondary to animal bites and other penetrating vascular injuries remain common. Globally, wars are a major source of vascular trauma, but this chapter deals predominantly with civilian injuries.

PRE-HOSPITAL CARE

Regional trauma systems, with hospitals designated to handle different levels of trauma, save lives by appropriate triage and timely, safe transfer of patients to

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specialised centres. These specialised centres have multidisciplinary teams with the skills and resources to manage patients with multisystem or critical injuries, which helps to optimise outcomes. Initial management begins at the place where and the time when the trauma occurs. Measures such as direct pressure on a bleeding wound or the application of a tourniquet on a limb above an injury help to save lives. The crucial first steps for extremity bleeding include appropriate splinting for long bone fractures and field dressings while applying pressure and elevation, topical haemostatics or dressings such as QuikClot®. In patients with profuse haemorrhage, for example from the neck, the insertion of a Foley urinary catheter, with inflation of the balloon to 15 mL and closure of the skin wound, has been described for low-velocity injuries. Permissive hypotension is preferable to attempts to normalise the blood pressure. Other agents such as calcium, tranexamic acid, whole blood resuscitation, packed red blood cells, plasma and platelets in a 1:1:1 ratio have also been described and are helpful when available.[6–8] Compression and stabilisation devices, such as pelvic fixators for pelvic fractures, can also be applied on site. Although not universally available, pre-hospital care and a robust transfer protocol is an essential part of a trauma system. However, in the absence of specialised high-volume trauma units, many lives can be saved by the fundamental principles outlined below.

PATIENT EVALUATION AND DIAGNOSIS OF VASCULAR INJURY

In addition to the the C-ABCDE (where the first C denotes catastrophic haemorrhage) approach to the overall management of injury, a specific history should be obtained. This should include the mechanism of injury; the time since injury; the details of pre-hospital care, blood loss and sensorimotor deficit; any known peripheral arterial disease; and medication history, including the use of antiplatelets or anticoagulants.

Obvious signs of vascular injury include active pulsatile bleeding, absent distal pulses, acute limb ischaemia, expanding or pulsatile haematoma, shock with evidence of haemorrhage and a bruit or thrill over an area of injury. On examination, an absent or diminished pulse or pain, pallor, paraesthesia, paralysis or paresis of a limb may be present. These signs may be difficult to ascertain in the presence of severe hypotension, in a comatose patient or in the presence of a tourniquet. However, a high degree of suspicion should always be maintained for vascular trauma and, until otherwise proven, the absence of a distal pulse should not be attributed purely to hypotension or spasm. Non-specific signs of vascular injury include a history of a major bleed, diminished distal pulse, a non-pulsatile haematoma and extensive soft tissue injury or fractures in the anatomical area of major blood vessels. In patients with penetrating trauma, the entry and exit wounds should be examined. This information, along with the number and the trajectory of wounds, may guide imaging and an operative plan. Certain injuries are known to be associated with a specific pattern of trauma (e.g. popliteal artery injury with posterior knee dislocation, subclavian artery injury with a fractured first rib, brachial artery injury with a supracondylar fracture of the humerus, calf compartment from a tibial plateau fracture, and blunt aortic injury from an acceleration–deceleration injury in a restrained driver in a car crash). A normal pulse can be present in 5–15 % of patients with delayed thrombosis, so ongoing neurovascular monitoring is essential. Relevant pulses must be examined hourly, both before and after vascular repair, before the operation under intraoperative sterile precautions is completed. A small intimal injury can rarely be managed conservatively with antiplatelet medication and continued observation.

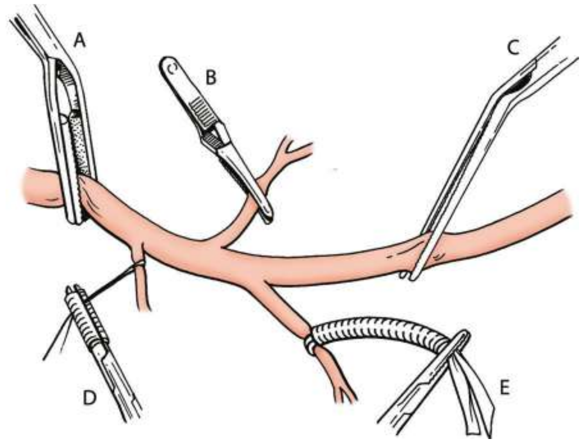
Initial resuscitation and imaging including focused abdominal sonogram for trauma (FAST) follow Advanced Trauma Life Support (ATLS) principles. Prevention of hypothermia, acidosis and haemodilution help prevent trauma-induced coagulopathy. In a stable patient, a Doppler examination of a distal pulse can be obtained and used to calculate an injured extremity index if possible. Reduced or diminished pulsation should be compared with the corresponding normal side and, if there is concern about a vascular injury, a computed tomography (CT) angiogram of the abdomen and pelvis, with bilateral lower extremity run-off, is indicated if available. This has high sensitivity and specificity for the diagnosis of traumatic arterial injuries, and both arterial and venous (delayed) phases should be obtained. In the extremity, delays in imaging may demonstrate collateral re-formation distal to the site of the injury. Some patients with obvious signs may require transfer to the operating room (OR) before imaging can be obtained. Controlled release of a tourniquet can be considered in some situations when major arterial/venous injury is not suspected. Placement of a resuscitative endovascular balloon occlusion of the aorta (REBOA) catheter can be considered, if available.[9,10] Ultrasound/duplex may be utilised on additional assessment after FAST, but should not delay definitive imaging or transfer to the OR or hybrid surgical radiological room (hybrid OR), if available, for definitive management.

OVERVIEW OF OPEN SURGICAL TECHNIQUES FOR VASCULAR RECONSTRUCTION

The management of vascular trauma requires a suitably equipped open surgical OR or a hybrid OR if this is available. Adequate light, suction and basic specific instruments are essential. The involvement of vascular surgeons and/or general/trauma surgeons varies depending on the acuity and availability, and skilled surgical consultation and involvement is obviously ideal when available. Intraoperative adjuncts include the availability of a Cell Saver and intraoperative duplex. The patient is rapidly widely prepped with skin antiseptic and draped. Continuous communication between multiple teams with a brief surgical timeout ensures the sequence of care, availability of equipment and personnel required to execute parallel procedures, the administration of antibiotics and tetanus prophylaxis. The exposure of vessels is critical, as proximal and distal control of the vessel is the first step. This may require access to the vessel in a different area (e.g. extraperitoneal control of iliac vessels for a vascular injury in the leg). A few additional aspects are described in the section 'Considerations for trauma-related vascular exposure by anatomic location'. Haemorrhage can be controlled either by direct pressure or with a proximal endovascular balloon. In this context, a Fogarty embolectomy catheter or, in a large vessel, a Foley catheter allows temporary proximal and distal control.

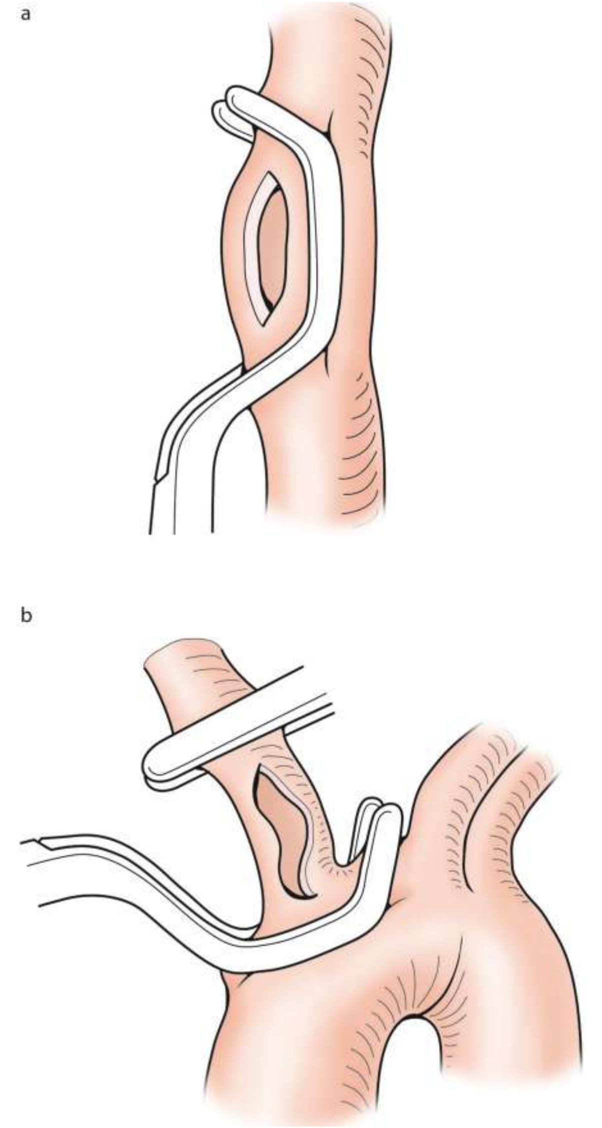
Overall, the open surgical techniques described in Chapter 19 for atherosclerotic disease are equally applicable to the management of trauma. Following proximal control, the wound is explored to identify the nature of the injury, which could be arterial or venous and is commonly both. The extent of intimal damage should be assessed. Proximal and back bleeding has to be assessed. Thrombus in the distal artery may require evacuation with gentle passage of a Fogarty embolectomy catheter.[11] If possible, administration of heparin should be considered, but this may not be feasible in the presence of concomitant intracranial injuries or major pre-existent coagulopathy. Intraluminal heparin washout is helpful.

Vascular control is secured by vascular clamps or silastic loops, placed above and below the site of an arteriotomy, or injury, as this is the most versatile method of control (Figure 18.1). Any of these methods should be used carefully, as, in the presence of concomitant atherosclerotic plaque or a flow-limiting dissection, local thrombosis or distal embolisation would further worsen ischaemic damage. With large vessel injury, application of a 'side-biting' clamp may allow distal perfusion (Figure 18.2). Once control is established, a proximal tourniquet, or balloon control, is gradually released, if the patient is haemodynamically stable and with discussion and agreement by the anaesthetist. In this phase, reperfusion may lead to hypotension, secondary to hyperaemia or blood loss, and reinflation of an occlusion balloon or a controlled re-clamp is an option. An appropriately sized vascular balloon or a Fogarty catheter are options to secure vascular control (Figure 18.3). For an extremity, this can be guided by an intraoperative duplex scan, but intrathoracic or intra-abdominal locations may require additional endovascular expertise. REBOA is discussed in the section 'Overview of endovascular techniques for vascular trauma'.



18.1 Vascular clamps and silastic loops: methods of controlling blood vessels. A, Fogarty soft jaw clamp; B, bulldog clamp; C, atraumatic metal-jawed vascular clamp; D, double ligature sling; E, sling with a vessel occluding snub. ⏎

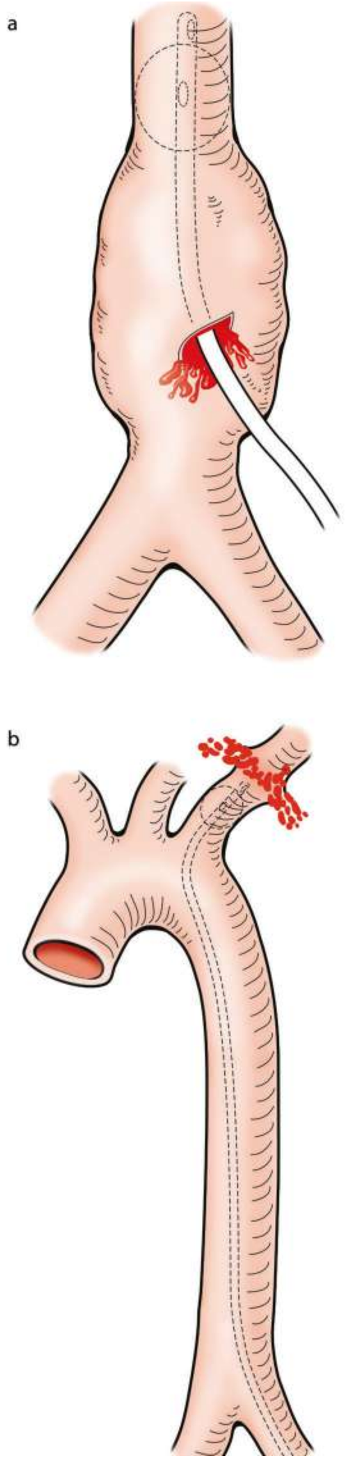
Damage control surgery must be considered in an unstable patient. An important part of damage control is the placement of external fixators and temporary shunts, which allow for an interval period of resuscitation, following which further definitive surgery can be performed. A temporary shunt is also indicated to reduce the duration of distal ischaemia (e.g. to allow fracture fixation of multiple unstable fractures). Traditionally, vascular repair is performed after fracture fixation, as a reconstructed vessel may be further damaged during skeletal manipulation if orthopaedic surgery follows vascular repair. Temporary vascular shunts are demonstrated in Figure 18.4. These include the Argyle (Cardinal Health, Dublin, OH, USA), Sundt (Integra, Plainsboro, NJ, USA), Javid (Bard PV, Tempe, AZ, USA) and Pruitt–Inahara (LeMaitre Vascular, Burlington, MA, USA). Shunts are sized to the proximal and distal vessel and secured in place with a silk tie. Systemic anticoagulation is not essential while the shunt is in place. Following placement, the shunt should be checked with Doppler to confirm flow. Complications of shunt placement include displacement or thrombosis, a higher risk in



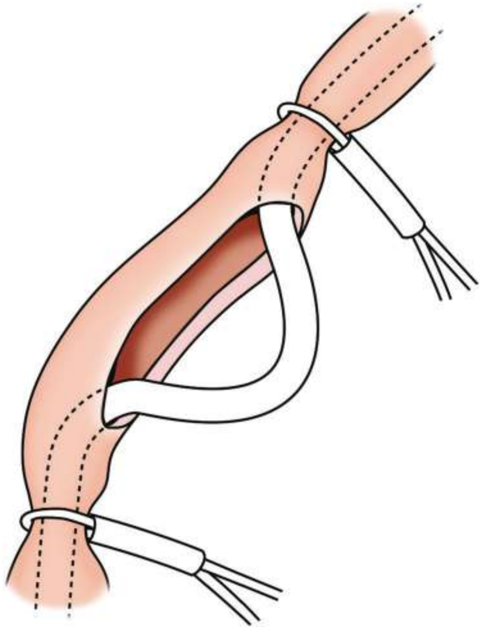
18.2 Side-biting clamp. An angled or curved side clamp can isolate part of the circumference of a large vessel while maintaining patency. (a) The control of an iatrogenic laceration in the inferior vena cava with a Satinsky clamp. The laceration can now be repaired without continuing haemorrhage. (b) A curved side clamp is isolating the root of the brachiocephalic artery with its traumatic tear. Flow through the aortic arch is maintained. ⏎

a small calibre artery or if the artery is intrinsically diseased. Although shunts can be retained for up to a day, or longer, these are usually removed with a definitive repair performed in 6–10 hours.

A small area of injury in an artery can be repaired with interrupted sutures. Vessels, if transected, can be mobilised to assess if a direct end-to-end repair is feasible. A cut edge of the vessel is inspected and, if necessary, the end of the arteries are freshened to obtain an area of healthy intima. Intima often retracts, so the end of the vessel may need spatulation

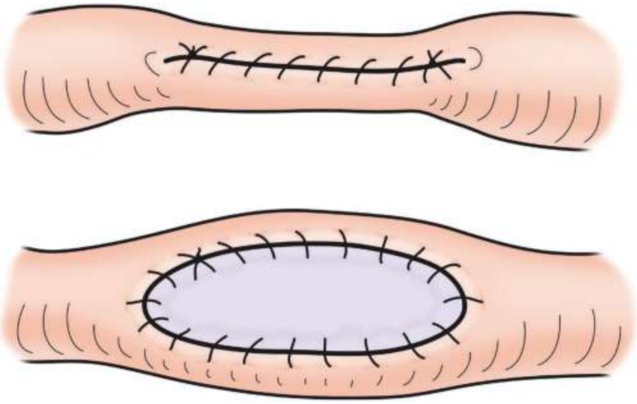


18.3 Fogarty catheter or vascular balloon. An intraluminal balloon catheter is valuable for proximal arterial control in situations in which direct access to the artery is difficult. (a) The catheter has been introduced through a ruptured aortic aneurysm to occlude the inflow. (b) Instead, the catheter has been introduced through the femoral artery to occlude the root of the subclavian artery proximal to a traumatic rupture. ⏎



18.4 Temporary vascular shunts. A temporary shunt maintains distal tissue perfusion while still allowing the surgeon good access in a dry field. ⏎

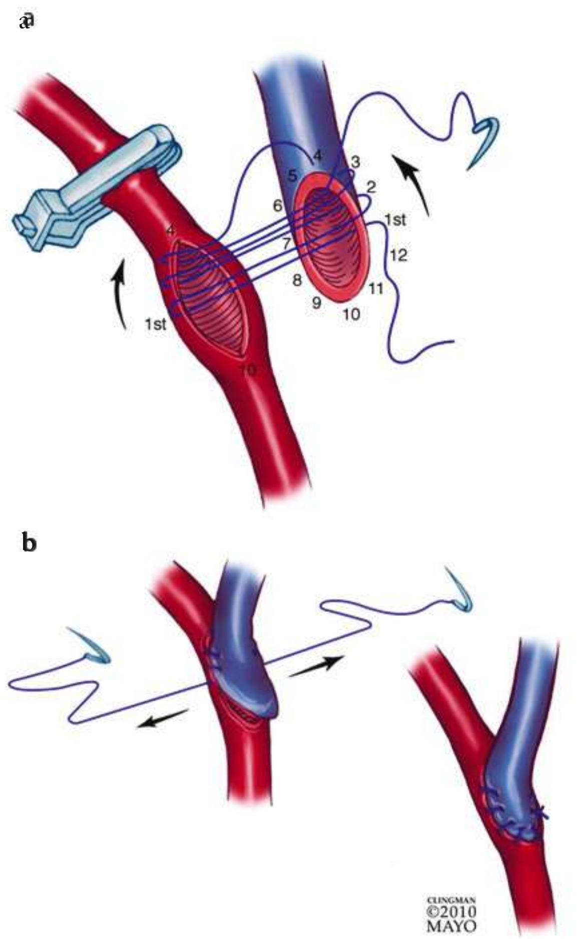
for a tension-free repair. Failure to adequately freshen the edge of the artery may result in an area of dissection, or intimal flap, which results in early thrombosis after reconstruction. If this is not feasible, an end-to-end anastomosis with an interposition vein graft may be required. A small arteriotomy, and passage of a Fogarty catheter, is usually not enough for thrombosis associated with vascular trauma due to the associated intimal injury, which is invariably present. Thus, if an area of arterial thrombosis without haemorrhage and an intact vessel is identified, following adequate control, the arteriotomy is usually created longitudinally. Following restoration of the inflow, and confirming backflow, closure of this defect is easily performed with a vein patch to avoid stenosis (Figure 18.5). Attempts should be made to identify and utilise vein as patch material to avoid the infection risk associated with prosthetic material in an infected, or potentially contaminated, field. Autogenous great saphenous vein (GSV) is the conduit of choice for a bypass. The vein is usually harvested from the contralateral extremity. However, ipsilateral veins, in the case of bilateral lower extremity trauma, or a small vein graft from other locations such as arm veins should also be considered. For a bypass, the GSV should be marked with ultrasound; this avoids unnecessary blind exploration, especially as the vein may be collapsed due to haemorrhagic shock. It is then harvested with skip skin incisions for a suitable vein length. It is always prudent to harvest a little more vein than necessary to allow a tension-free anastomosis. The GSV is also ideal for a vein patch; however, ideally, the proximal GSV should not be sacrificed for a patch alone. For a patch, a segment of the distal GSV or a large tributary is recommended. The patch is anastomosed either with a parachute technique or by tying down the patch at one end (Figure 18.6). In older patients, at certain locations (e.g. the common femoral artery), concomitant endarterectomy may be required, as described in Chapter 19. A bovine pericardial patch can be used if a suitable vein is not available, as this is considered to be a little more resistant to infection, has less suture hole bleeding and handles better than other non-autologous alternatives. Other patch/graft materials include expanded polytetrafluoroethylene (e-PTFE) or Dacron™ (polyester) and are described in Chapter 19.



18.5 Vein patch. Simple closure of an arteriotomy may result in a stenosed segment. This can be avoided by using a vein patch. ⏎

A vascular anastomosis, or repair, is usually performed using double-armed polypropylene sutures. Repair of large arteries and veins, such as the aorta or the inferior vena cava, may require 3/0 or 4/0 suture strength, with extremity repair usually performed with 5/0 or 6/0 Prolene. The repair can be performed using a single, or two continuous, running suture(s) in a large vessel. In children, or when the vessels are small, interrupted sutures may be required for repair. Overall, the objective is to suture the intimal edges with slight eversion.

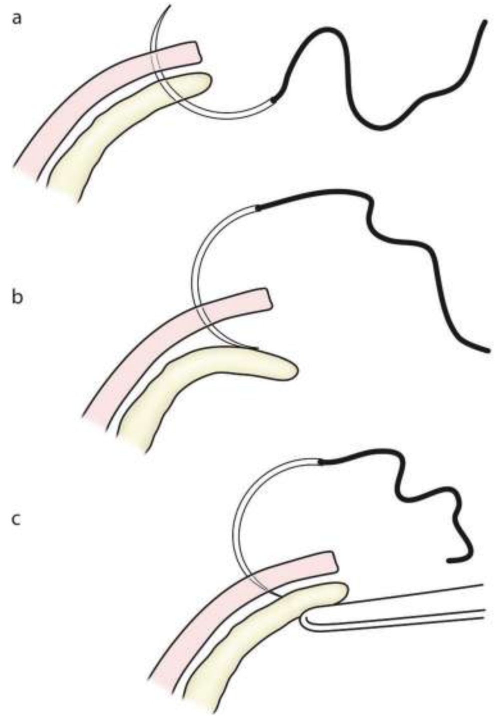
A vascular repair is usually performed with a needle passed from the intima outwards to the adventitia, as a needle passed from outside the artery to inside is more in danger of lifting an intimal flap. However, in certain situations, such as in an end-to-end anastomosis, a needle may be passed from outside inwards and this is performed carefully with the intima supported from the inside, ensuring that the needle travels through all arterial layers at 90° without raising a flap (Figure 18.7). A detailed description of vascular surgical techniques is beyond the scope of this chapter, but basic precautions include careful handling of the polypropylene suture and not holding the suture with



18.6 The patch is anastomosed either (a) with a parachute technique or (b) by tying it down at one end. (Used with permission of Mayo Foundation for Medical Education and Research, all rights reserved.) ⏎

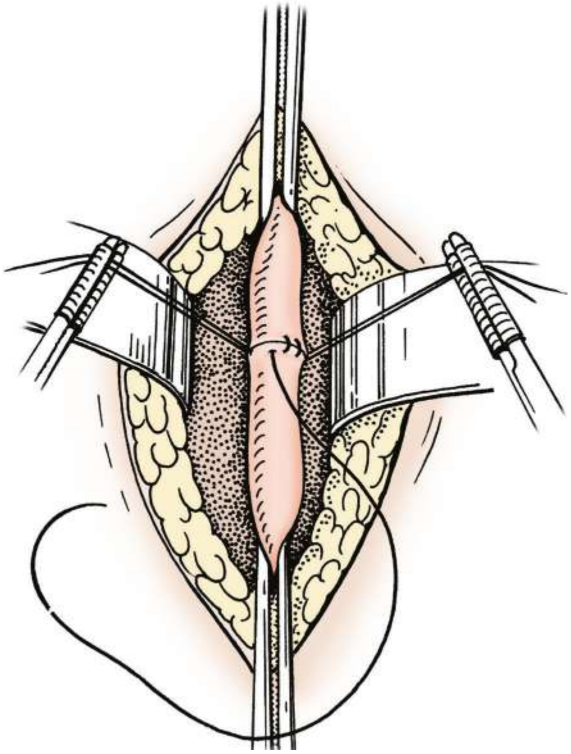
metal instruments, as this leads to suture fracture and may lead to delayed breakage and bleeding once the suture line is subject to arterial pressure. One end of the suture is usually held with a rubber-shod clamp during the repair.

End-to-end anastomoses can be difficult if one or both ends of the vessel are freely mobile. Stay sutures, placed as three interrupted anchors equidistantly around the circumference, will help (Figure 18.8). More commonly, a posterior row of continuous sutures is initially placed intraluminally, with the cut ends of the vessel still some distance apart (Figure 18.9). The frictionless quality of polypropylene allows the ends to be parachuted together. The front of the anastomosis is then continued from outside, using both ends of the double-ended suture. Vessels (and grafts) are 'flushed' prior to completing an anastomosis. Flushing is initially performed by releasing the proximal and distal clamps in turn to expel the blood, and possible clots, from the vessel immediately above and below the anastomosis. Heparinised saline is then injected intraluminally, both upstream and downstream, to rinse the vessel free of any thrombus or plaque debris that could cause distal emboli. The anastomosis is then completed and the two ends of the suture are tied together before the clamps are finally released. Minor leakage from an anastomosis will cease with local pressure or haemostatic agents. Areas of significant bleeding will require a further suture. Clamps should be reapplied before inserting further sutures, as the vessel may tear and the situation worsen if a suture is inserted with a poor view of the anastomosis. Either figure-of-eight or mattress sutures are used and can be buttressed with bovine pericardial, Dacron™ or PTFE pledgets or, alternatively, with an autologous pledget of abdominal wall fascia, a section of vein or even a small piece of fat taken from the patient's tissues.

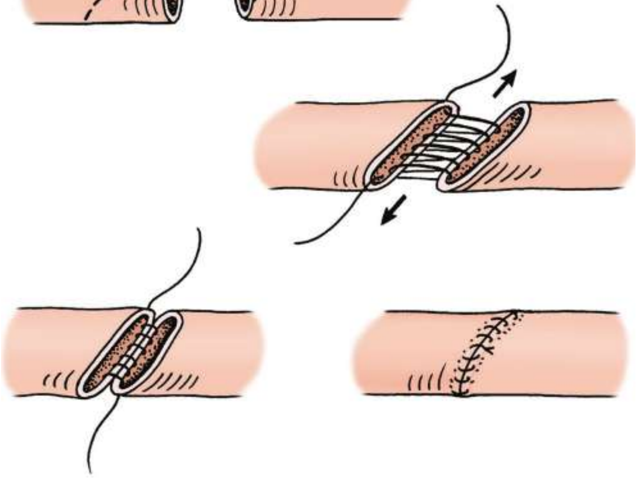


18.7 Passing the needle without raising an intimal flap. (a) A needle passed from inside out presses an intimal atheromatous plaque safely against the vessel wall. (b) When passed from outside inwards, it may separate off the plaque and initiate a dissection. (c) This separation is prevented by supporting the intima with an instrument. ⏎

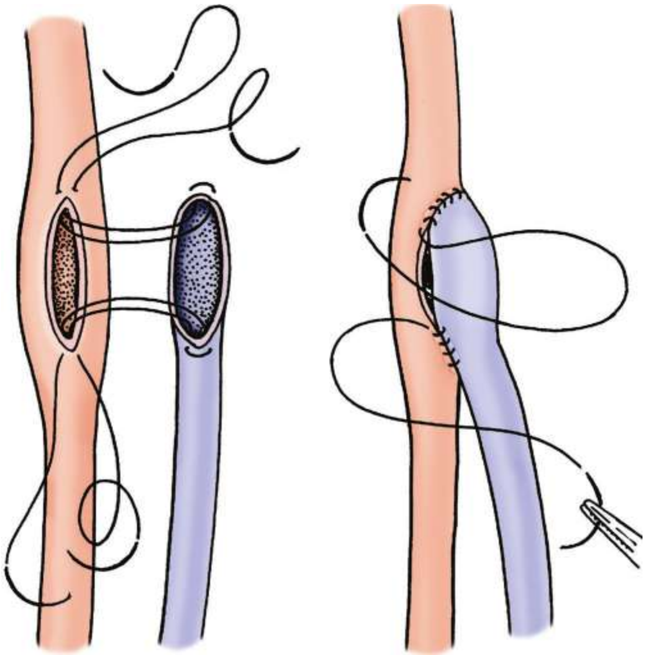
An end-to-side anastomosis follows similar principles and is most commonly performed between a diseased vessel and a bypass graft. An arteriotomy in the vessel, two or three times longer than the diameter of the graft, forms the 'side' for the anastomosis. The 'end' of the artery, vein or synthetic graft is bevelled, as this allows it to lie naturally without kinking, reduces the angulation that causes blood flow turbulence and produces a wider end for the anastomosis. An incorrect angle will predispose to folding or kinking. This may happen in some situations if the final position of the vessels on closure of the wound is not taken into consideration. If access is unrestricted, a double-ended suture is placed first at the 'heel' and a second similar suture is placed at the 'toe' (Figure 18.10). All sutures can then be placed from outside. If access is more restricted, a double-ended suture is placed at the heel and then the back row of continuous sutures is placed from within before the ends are parachuted into apposition. The anterior portion of the anastomosis is then completed from the outside (Figure 18.11). Continuous or interrupted sutures, or a combination, are suitable. A continuous suture is more haemostatic and quicker, but may narrow the heel or toe of a graft anastomosis. Interrupted sutures, particularly if left untied until all have been placed, allow a clear view for the insertion of each stitch, but the process is time consuming and the artery may distort unexpectedly as the edges are drawn together. For some anastomoses, a hybrid technique can be employed, namely a continuous line of sutures, for the most part, with interrupted stitches at the heel and especially the toe of the anastomosis. A few moments' consideration regarding the set-up and orientation of the anastomosis is always worthwhile. The access and view should be good for the key areas of the heel and the toe, the direction of travel should minimise



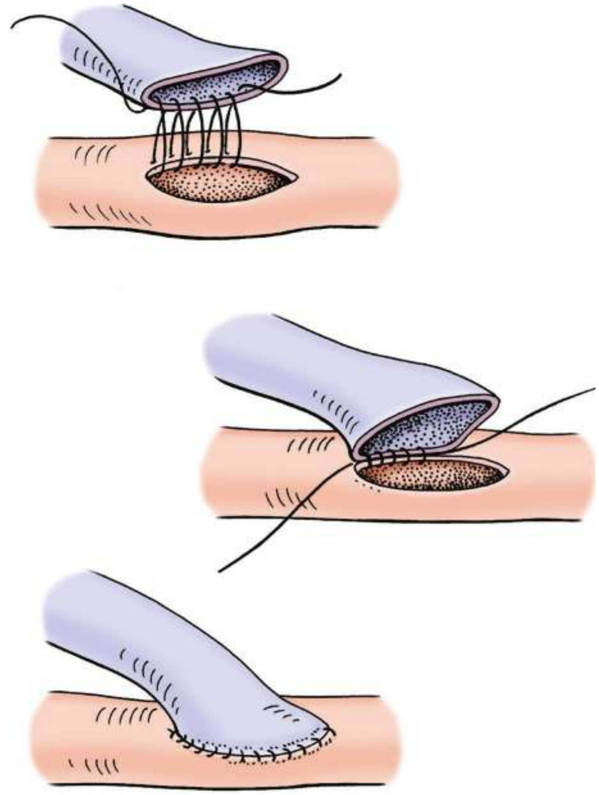
18.8 Stay sutures/anchoring sutures. Interrupted anchoring sutures are placed first to unite the vessel equidistantly around the circumference. The ends of these sutures are left long and held in forceps. The anastomosis is then performed with a continuous suture between these anchoring sutures, which are used to rotate the vessel for access. The continuous suture should slightly evert the edges. ⏎



18.9 Posterior continuous sutures. When access or mobility is too poor for the technique illustrated in Figure 18.8, a running, posterior monofilament suture draws the ends together and is continued around the front of the vessel. ⏎



18.10 Heel and toe. The initial anchoring sutures have been placed at the heel and toe of the anastomosis between the native artery and the vein graft and, as access is unrestricted, the remainder of the anastomosis will be completed from without. ⏎



18.11 Completion of the front of the anastomosis from without. When access is limited, the initial stitch with a double-ended suture should be at the heel, and the back of the anastomosis is completed from within in a similar fashion to that illustrated in Figure 18.9. The front of the anastomosis is performed from without and, on completion, the two ends of the suture are tied together. ⏎

crossing of sutures and the anastomosis should be finished on the side closest to the operator, especially in narrow, confined areas such as the popliteal fossa.

In broad terms, vascular injuries at, or above, the level of the knee and elbow require repair. Arterial ligation is an option in extremity injury where the injury is very distal and there is a robust collateral pathway. This includes ligation of a distal single tibial or peroneal artery injury in a younger patient in whom the other two vessels supplying the leg are in continuity. A similar ligation for a distal radial or ulnar artery injury in a patient with an intact palmar arch is an option. This needs to be individualised; in the presence of major soft tissue injury requiring soft tissue transfer/free flap coverage, a transected vessel with the preserved inflow and outflow may be utilised for the flap. Ligatures are usually non-absorbable suture material such as silk, of appropriate size and strength. Transfixing a vessel for closure, oversewing in one or two layers or arterial stapling devices can also be utilised.

OVERVIEW OF ENDOVASCULAR TECHNIQUES FOR VASCULAR TRAUMA

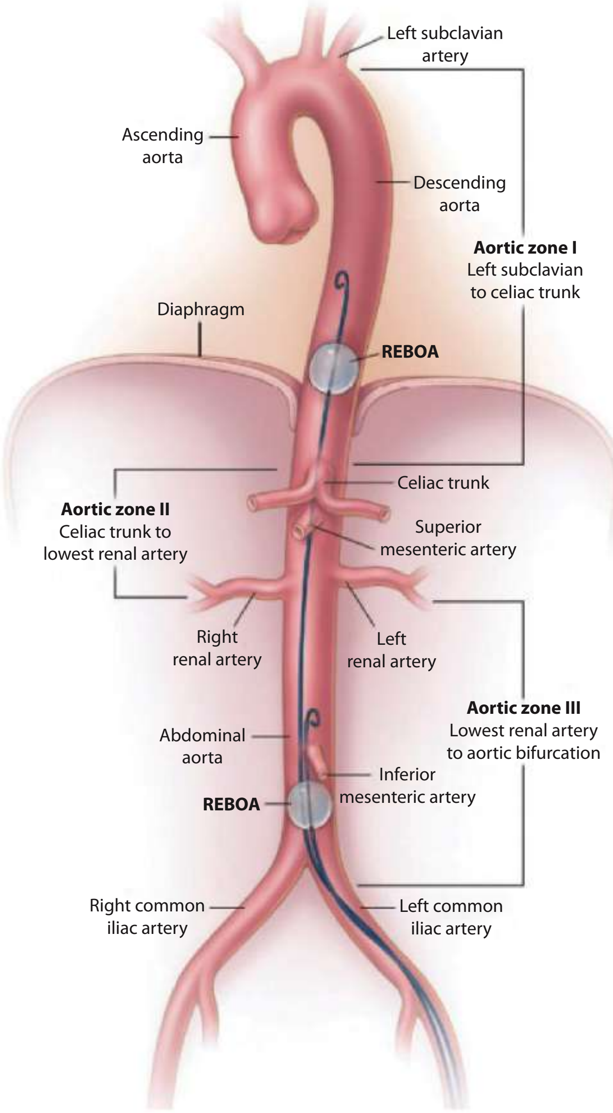
Traditionally, the endovascular interventional radiology suite and the OR were separate locations, and transferring a patient between sites, especially a haemodynamically unstable patient, is difficult. In an OR, the use of a C-arm as an adjunct for management can be considered, but this requires specific planning, as the need for intraoperative fluoroscopy would require specific patient positioning and a compatible OR table. More recently, the evolution of hybrid trauma ORs has enabled integrated multidisciplinary care, although such complex facilities are scarce and are predominantly only in high-income countries.

Patients with solid organ injury, high-grade splenic injury and, rarely, parenchymal liver lacerations, renal injury with continued bleeding, pseudoaneurysms, large fistulas or persistent haematuria may require embolisation with coils or plugs. Pelvic fractures are predominantly associated with venous bleeding, with arterial injury present in about 15%. However, unrecognised arterial injury leads to high mortality from pelvic fractures. Bleeding is usually from branches of the internal iliac artery, and angioembolisation of distal branches (and not the mainstem vessels) such as the superior gluteal, internal pudendal, iliolumbar, inferior gluteal or lateral sacral should be considered. Distal vessel embolisation is particularly relevant when bilateral angioembolisation is required to prevent gluteal necrosis or spinal and pelvic ischaemia. Temporary balloon control of bilateral internal iliac arteries can be performed to reduce bleeding before surgical pelvic fixation.

Injury to junctional arteries (e.g. an iliac/femoral, axillary or subclavian artery), blunt thoracic aortic injury, and intrathoracic or high carotid and vertebral artery injuries are other situations in which endovascular management has improved patient outcomes. In these situations, ultrasound-guided percutaneous or open vascular access is obtained, either in the femoral arteries or distal to the site of injury, securing rapid proximal control followed by the placement of a covered stent. Stents can be self-expanding or balloon expandable and are usually sized 1:1 to the artery where the stent is being placed. A few specific scenarios in which endovascular management is the optimal treatment are described in the subsequent sections.

REBOA was developed for control of intracavitary haemorrhage. REBOA involves obtaining arterial access to the femoral artery, either based on surface marking or using fluoroscopy, placement of a femoral sheath of appropriate size and length, and balloon control with the ER-REBOA catheter (Prytime Medical, Arvada, CO, USA) or alternatively with

Coda (Cook Medical, IN, USA); Reliant (Medtronic, MN, USA) or Berenstein (Boston Scientific, MA, USA) balloons. Aortic control is obtained proximal to the location of the vascular injury. There are three anatomically defined zones in REBOA occlusion techniques. Zone 1 extends from the origin of the left subclavian artery to the coeliac artery and is an occlusion zone for high-grade liver, spleen or renal injury or mesenteric vascular injury (Figure 18.12). Zone 2 extends from the coeliac artery to the lowest renal artery and is not an occlusion zone. Zone 3 is defined from the lowest renal artery to the aortic bifurcation and is an occlusion zone for pelvic and junctional femoral (contralateral) haemorrhage.[12,13]


Left subclavian artery
Ascending aorta
Descending aorta
Aortic zone I
Left subclavian to celiac trunk
Diaphragm
REBOA
Celiac trunk
Aortic zone II
Celiac trunk to lowest renal artery
Superior mesenteric artery
Right renal artery
Left renal artery
Aortic zone III
Lowest renal artery to aortic bifurcation
Abdominal aorta
Inferior mesenteric artery
REBOA
Right common iliac artery
Left common iliac artery

18.12 Zones of aorta during REBOA zone 1: origin of left subclavian to origin of coeliac artery. (Reproduced from Burg et al.,[14] licensed under CC BY 4.0, available at https://link.springer.com/article/10.1007/s00068-022-02033-7/figures/1.) ⏎

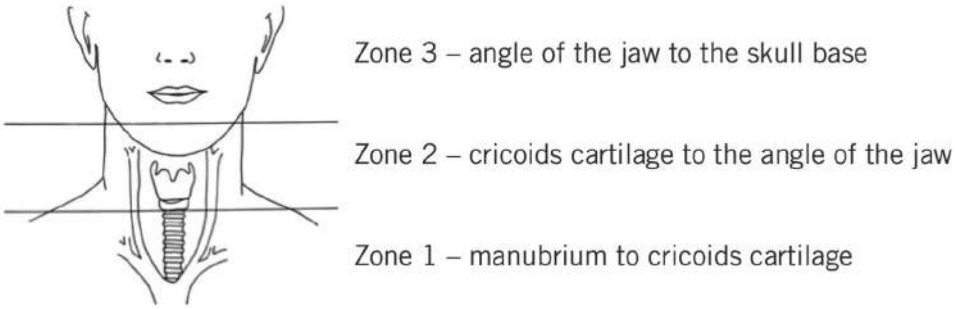
Although REBOA has not been universally accepted and is not widely available, it has a definite role in the trauma resuscitation tool kit. The duration of balloon inflation is usually limited to 30 minutes in zone 1, with a longer inflation duration if needed in zone 3. Following resuscitation, the balloon is deflated as early as possible. The balloon is slowly deflated; reinflation is an option if further bleeding occurs but, ideally, the balloon is removed as soon as possible. The femoral sheath should be flushed continuously while in place, with sheath removal after reversal of existent coagulopathy. A percutaneous closure device can be used to close the arteriotomy if a sheath greater than 6 French is used. Access site complications can occur in 1–10%, with reperfusion complications similar to reperfusion problems after an aortic cross-clamp.

CONSIDERATIONS FOR TRAUMA-RELATED VASCULAR EXPOSURE BY ANATOMIC LOCATION

HEAD AND NECK

Injuries in the head and neck are challenging due to the close proximity of the subclavian, carotid and vertebral arteries, the jugular veins, the oesophagus, the trachea and the spine. There is a high rate of vascular injury in penetrating trauma to the head and neck. Blunt cerebrovascular injury can also occur and may be associated with a delayed stroke rate as high as 20% if not appropriately diagnosed and treated. Presentation may include obvious or subtle signs, as well as anterior or posterior circulation neurological symptoms, Horner syndrome, headache and/or facial pain. Concomitant aerodigestive tract injuries, brachial plexus injuries and venous injuries should be suspected. A CT angiogram of the head and neck, with imaging including the aortic arch, is the optimal investigation tool, if available. CT angiography should be specifically considered in those with risk factors such as trauma associated with a severe neck hyperflexion, hyperextension or whiplash-type injury; a LeFort 2 or 3 fracture; presentation with a Glasgow Coma Scale score of less than 6; or cervical fractures with pain and swelling, clinical signs of altered mental state, traumatic brain injury with thoracic injuries and scalp degloving.[15]

Injuries to the neck are assessed in accordance with Monson's zones: zone I spans from the clavicle to the cricoid cartilage, zone II spans from the cricoid cartilage to the angle of the mandible and zone III spans from the angle of the mandible to the skull base (Figure 18.13).[16] Injury within zone II is usually managed with operative exploration, as control of the common carotid artery and the distal external and


Zone 3 – angle of the jaw to the skull base
Zone 2 – cricoids cartilage to the angle of the jaw
Zone 1 – manubrium to cricoids cartilage

18.13 Monson's zones. (Reproduced from Harris et al.,[17] licensed under CC BY 3.0, available from https://publishing.rcseng.ac.uk/doi/10.1308/003588412X13171221590052.) ⏎

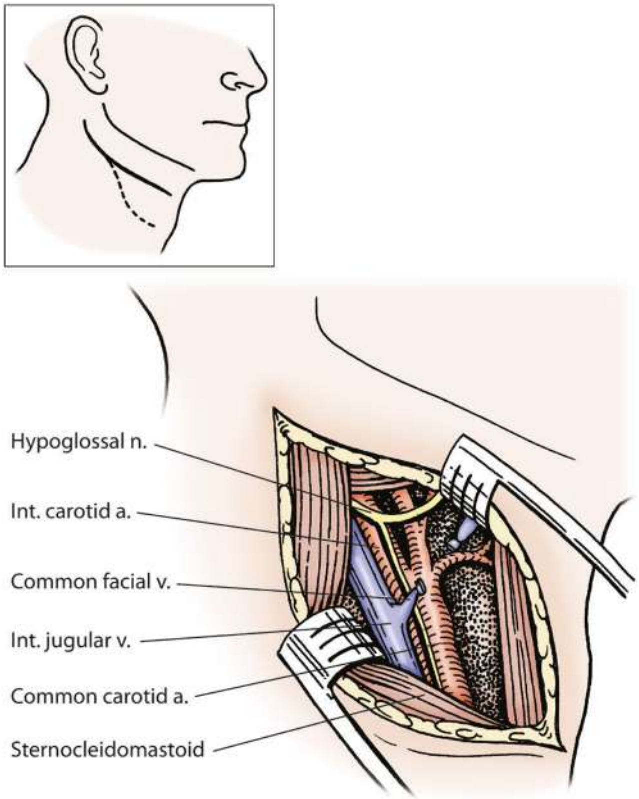
internal carotid artery can be obtained in the neck. In injuries within zone I, proximal endovascular control or consideration of sternotomy is required. Injuries within zone III may require high exposure, including division of the digastric, division of the occipital artery or consideration of endovascular control.

Anatomy and exposure

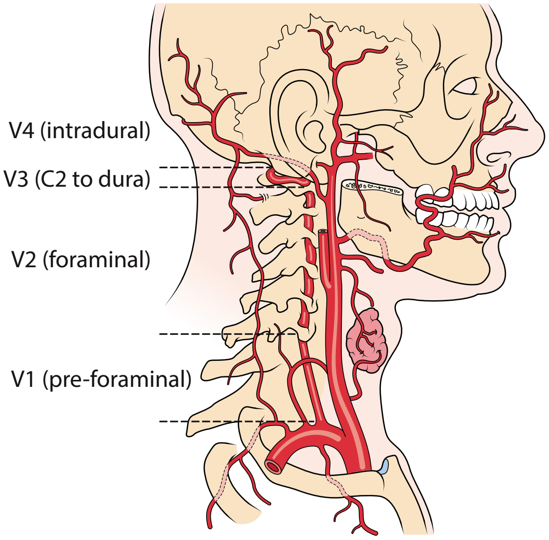
The common carotid artery begins its course in the neck behind the sternoclavicular joint. It ends in a bifurcation, usually opposite the upper border of the thyroid cartilage, forming the external carotid artery (ECA) and the internal carotid artery (ICA). The common carotid artery is enclosed, along with the internal jugular vein and the vagus nerve, in the carotid sheath of deep cervical fascia; the vein is lateral to it and the nerve lies posterolateral, in the groove behind the two vessels. The ECA runs upwards from the carotid bifurcation to end behind the mandible, by dividing into its terminal maxillary and superficial temporal branches. The ECA leaves the carotid triangle by passing under cover of the posterior belly of the digastric muscle, and its upper part occupies a groove on the deep surface of the parotid gland or lies within the gland. It is the major vascular supply to the neck, face and scalp. There are three large anterior branches: the superior thyroid, the lingual and the facial. The occipital and posterior auricular are posterior branches. The ICA ascends from the carotid bifurcation to enter the skull through the carotid canal, just posteromedial to the temporomandibular joint. The ICA is at first posterolateral to the ECA and then deep to it. It is enclosed in the carotid sheath, with the internal jugular vein laterally and with the vagus nerve deep in the space between them; at the skull base, the vein is posterior to the artery. There are no branches in the neck and the ICA supplies purely intracranial structures.

Preoperative preparation usually includes the chest and thigh. The head is turned to the opposite side and the neck is slightly extended. This can be achieved by replacing the pillow with a 'head ring' and lowering the 'head' of the operating table or by placing a sandbag between the shoulder blades. The ideal cosmetic incision is in a skin crease, but the best exposure of the carotid vessels in an emergency is through a long oblique incision along the anterior border of sternocleidomastoid. If required, this can be extended into a midline sternotomy. In order to avoid damage to the cervical branch of the facial nerve, the upper end of the incision should be kept about a fingerbreadth away from the angle of the mandible, curving back towards the mastoid. The platysma and deep fascia are divided in line with the skin incision, and the external jugular vein is ligated and divided.

The anterior border of sternocleidomastoid is freed and the muscle retracted posteriorly. The common facial vein lies superficial to the common carotid artery and crosses the common carotid just below the bifurcation (Figure 18.14). This vein is ligated and divided, after which the internal jugular vein can be displaced backwards to expose the carotid arteries more fully. The ansa cervicalis can usually be identified on the common carotid artery and traced up towards its junction with the hypoglossal nerve. The main hypoglossal nerve crosses superficially to the carotid arteries, just above the bifurcation, and has to be identified and preserved. The ansa can be divided if necessary. At the upper extremity of the dissection, the carotids lie deep to the parotid gland and the posterior belly of the digastric. Division of the posterior belly of the digastric and ligation of the occipital branch of the external carotid allow additional exposure of the distal ICA. Care should be taken to protect the glossopharyngeal nerve, which lies just deep to the posterior belly of the digastric. Following exposure, the extent of injury is assessed and a small injury can be closed primarily. This may be the situation with an iatrogenic injury from a central line placement. Following proximal and distal control, the area of injury is used as the site for an arteriotomy. Backflow from the distal ICA is assessed quickly, any obvious thrombus in the ICA is 'milked' back and a



18.14 Exposure of the common carotid artery. An oblique incision along the anterior border of the sternocleidomastoid gives better carotid access than the transverse incisions shown in the inset. The sternocleidomastoid muscle is retracted posteriorly and the common facial vein is divided to display the carotid bifurcation. ⏎



18.15 Segments of the vertebral artery. ⏎

careful thrombectomy with a 2 or 3 Fogarty embolectomy catheter can be performed. With embolectomy, the catheter can be pre-measured on the skin surface to avoid entering too much of the carotid siphon, avoiding the creation of a carotico-cavernous fistula. Radiological guidance can be utilised if available. Once backflow has been restored, repair is performed with either a patch or a bypass, usually utilising a GSV conduit. Concomitant aerodigestive injuries need to be addressed. Injury to the ICA or common carotid needs repair; the ECA can be ligated if repair is not feasible. Following repair, the wound is closed over a drain, prophylactic antibiotics are continued and antiplatelet therapy with aspirin is initiated for at least 3 months. Endovascular management of a more distal injury with placement of a covered stent may require dual antiplatelet therapy for at least 3 months. Postoperatively, the patient should be woken up for an assessment of the neurovascular status as early as possible depending on concomitant injuries. Blood pressure control is important, with mean blood pressure maintained between 70 and 90 mmHg, avoiding hypertension or hypotension and avoiding hypoxia. In patients in whom intracranial haemorrhage follows repair, or in a stroke without any technical problems with the vascular repair, the management is similar to that of stroke.

Blunt cerebrovascular injury, as well as arterial dissection, or a non-flow-limiting injury in a neurologically intact patient can occasionally be managed non-operatively. Initial management is by an intravenous heparin infusion, and either antiplatelets or antithrombotic therapy is initiated once the patient is clinically stable. Serial vascular imaging is performed. Patients with flow-limiting stenosis, enlarging pseudoaneurysms or development of arteriovenous fistula may require an endovascular stent placement. Injury to the jugular vein is usually suture repaired but can be ligated. Patients with bilateral jugular vein injury should have one side preserved to avoid cerebral oedema.

The vertebral arteries are divided into four segments: the first (V1) extends from the subclavian artery at its origin until its entry into the C6 transverse foramen; the second part (V2) extends from this point until its exit from the bony canal at C2 (Figure 18.15); the third part (V3) extends from C2 to the base of the skull; and the fourth part (V4) is the intracranial segment. The V1 segment of the vertebral artery can be accessed from the neck through a medial transverse supraclavicular incision. However, this may be difficult in the presence of a large haematoma, with the possibility of injury to the vagus nerve, thoracic duct and surrounding vascular structures. Unilateral ligation of the artery is an option. Injury to the vertebral artery is usually managed endovascularly, with covered stent placement or coiling.

AXILLO-SUBCLAVIAN AND UPPER EXTREMITY INJURIES

Although upper extremity vascular injury is less common than lower extremity injury, it can be associated with high mortality and morbidity if there is a missed junctional artery injury. Mechanisms of injury can be secondary to penetrating trauma, as well as to motor vehicle collisions, blast injury or bony fractures.

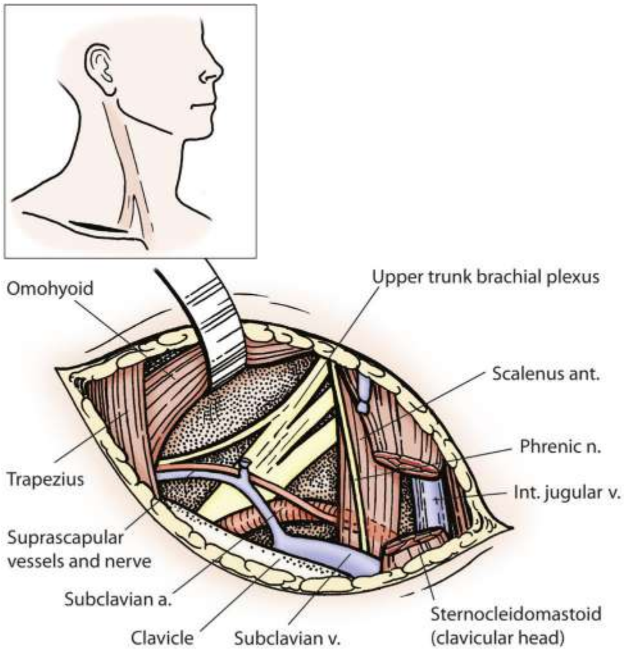
Anatomy and exposure

The subclavian artery crosses the front of the cervical pleura at the root of the neck. It arches from behind the sternoclavicular joint to the outer border of the first rib, where it becomes the axillary artery. It rises to a level of 1–2 cm above the clavicle when the shoulder is depressed. The scalenus anterior crosses anterior to the artery. The first part of the artery is defined as the portion that lies medial to the scalenus anterior; the second part lies behind this muscle and the third part lies lateral to the scalenus anterior. The subclavian vein lies in front of the scalenus anterior, at a lower level than the artery, and behind the clavicle. The axillary artery runs downwards and laterally behind the clavicle into the roof of the axilla and continues as the brachial artery at the lateral border of the axilla. The axillary artery is divided into three parts by the pectoralis minor, which crosses anterior to the second part. The axillary vein lies just below, and medial, to the artery throughout its course, and the brachial plexus lies in close association with the artery. The brachial artery is the continuation of the axillary artery from the level of the lower border of the teres major. It runs inferiorly, and slightly laterally, at first medial and then anterior to the humerus. It ends at a bifurcation in the cubital fossa, at the level of the neck of the radius, by dividing into radial and ulnar arteries. The artery is accompanied by venae comitantes in its lower part and by the basilic vein in the proximal upper part. In the arm, the median nerve is initially lateral to the brachial artery but then crosses in front of the middle third of the artery to run along its medial side. The ulnar nerve is on the medial side of the artery in its upper half, but diverges from its lower half to run behind the medial epicondyle of the humerus. The median cutaneous nerve of the forearm also lies to its medial side in the upper half of the arm. At the front of the elbow, the brachial artery enters the cubital fossa, with the tendon of the biceps on its lateral side and the median nerve on its medial side. The artery and nerve are deep to the deep fascia and the bicipital aponeurosis, which stretches from the tendon of the biceps to blend with the deep fascia over the medial side of the forearm.

Exposure of the first and second parts of the subclavian artery requires division of the clavicular head of the sternocleidomastoid and division of the scalenus anterior, followed by medial retraction of the internal jugular vein. The phrenic nerve, lying on the surface of the scalenus anterior, should be preserved and held in a sling to retract it out of the operative field. The common carotid artery is obscured by the internal jugular vein. Lateral retraction of the vein exposes the common carotid artery. The artery can be gently mobilised, and retracted upwards, by means of a vascular sling or tape passed around it. The supraclavicular incision can be combined with a median sternotomy, in which case the sternal head of the sternocleidomastoid is also divided (see Figure 23.4a). This gives the extensive exposure necessary to gain control of the proximal subclavian, or the brachiocephalic trunk, in major cardiac trauma.

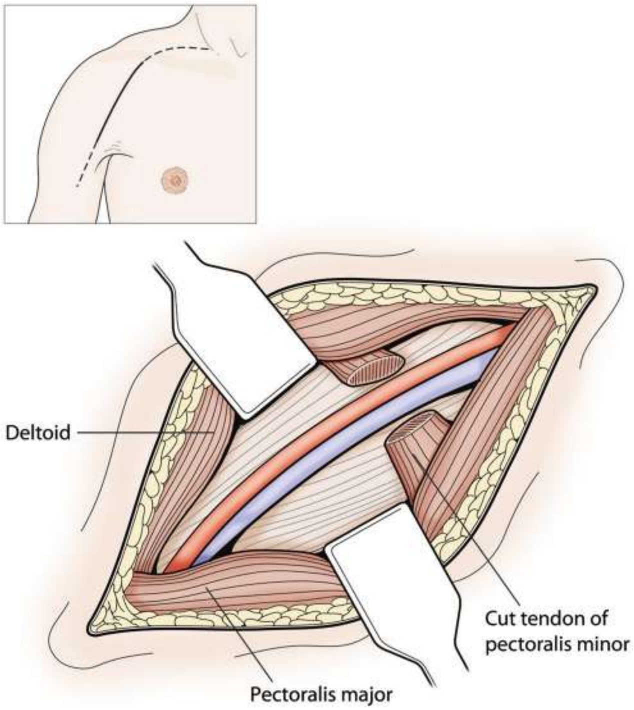
The third part of the subclavian artery is the most surgically accessible. In trauma, when extensive exposure of the artery is required, the third part is often exposed initially and then the incision is extended medially. A limited exposure of the third part of the subclavian artery is occasionally indicated when there is uncontrollable haemorrhage from the axillary artery. A temporary clamp on the subclavian artery will then provide some proximal control during exploration of the axilla. Ideally, the damaged axillary artery is then repaired, or reconstructed, but simple ligation of the third part of the subclavian artery is another option. Perfusion of the upper limb is safeguarded by collateral vessels around the shoulder, which are perfused by branches arising from the proximal subclavian artery. The arm is placed at the side and drawn downwards in order to depress the shoulder; the head is turned to the opposite side. An incision is made 1–2 cm above the clavicle from the sternal head of the sternocleidomastoid to the anterior border of the trapezius (Figure 18.16). The superficial fascia and platysma are incised in the same line and the deep fascia divided. The external jugular vein may cross the operative field and may have to be divided between ligatures. A supraclavicular nerve may also have to be sacrificed. The omohyoid is retracted upwards and the third part of the subclavian artery is now exposed, with the upper and middle trunks of the brachial plexus lying superolaterally. The suprascapular artery, which arises from the thyrocervical branch of the first part of the subclavian artery, crosses the operative field as it runs superolaterally, anterior to the subclavian artery, with its accompanying vein and nerve.

Axillary artery exposure is easiest with the upper limb partially abducted, and supported, on an arm

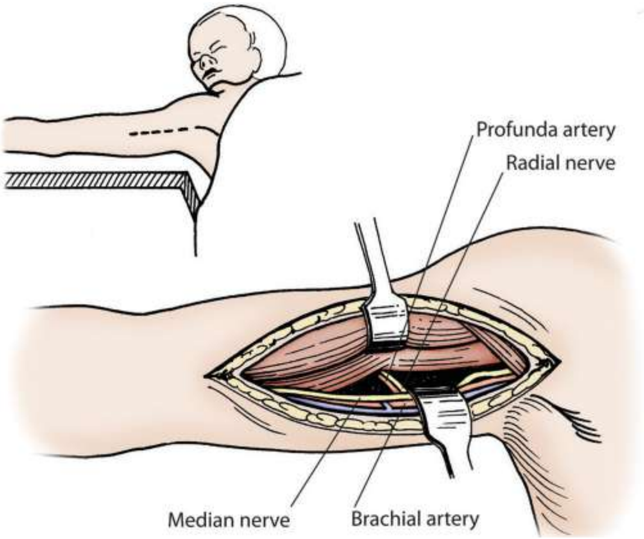

Omohyoid
Upper trunk brachial plexus
Scalenus ant.
Phrenic n.
Trapezius
Int. jugular v.
Suprascapular vessels and nerve
Subclavian a.
Clavicle
Subclavian v.
Sternocleidomastoid (clavicular head)

18.16 Exposure of the subclavian artery. The incision for exposure of the subclavian artery is above and parallel to the clavicle. The omohyoid is retracted and the subclavian artery is visible between the scalenus anterior and the brachial plexus. Division of the scalenus anterior and medial retraction of the internal jugular vein exposes the proximal subclavian artery. When more extensive exposure of the vascular root is required, the internal jugular can be retracted laterally or the incision can even be extended to combine it with a median sternotomy. ⏎

board. The incision for an extensive exposure is along the deltopectoral groove from the lower border of the clavicle to the lower border of the anterior axillary fold (Figure 18.17). Anterior branches of the axillary artery and the termination of the cephalic vein will be encountered. The cords of the brachial plexus lie around the artery and the axillary vein lies inferomedially. The tendon of the pectoralis minor is divided. This incision can be extended downwards to expose the brachial artery (Figure 18.18). The incision can also be extended proximally to join with a supraclavicular incision and provide extensive simultaneous access to both the subclavian and the axillary arteries. The clavicle crosses the operative field, but can often be left intact. However, the root of the neck is a hazardous area for an inexperienced surgeon. The subclavian artery is relatively thin walled, and bleeding from this artery, or from one of the great veins, is very difficult to control. In emergency situations, when rapid control of both the third part of the subclavian and the first part of the axillary artery may be essential, there should be no hesitation in dividing pectoral muscles and resecting the middle third of the clavicle.

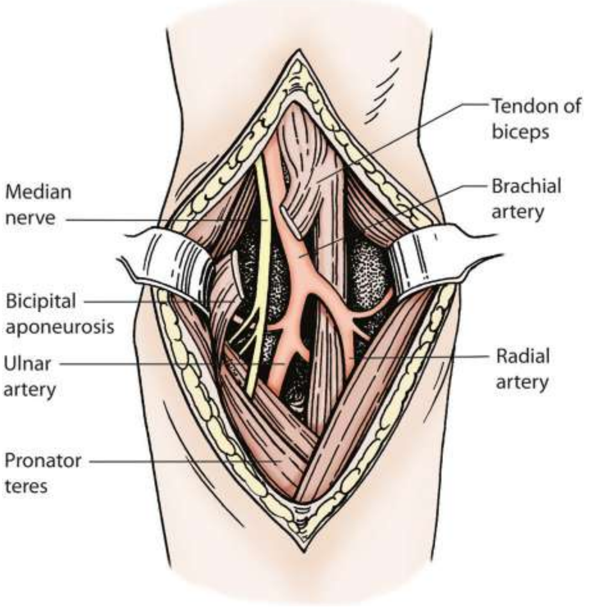

Deltoid
Cut tendon of pectoralis minor
Pectoralis major

18.17 Exposure of the axillary artery. The axillary artery is approached via an incision along the deltopectoral groove. It can be extended proximally if simultaneous access to the subclavian artery is required or distally to expose the brachial artery. Division of the pectoralis minor and retraction of the pectoralis major and deltoid exposes the artery. ⏎


Profunda artery
Radial nerve
Median nerve
Brachial artery

18.18 Exposure of the brachial artery in the right upper arm. ⏎

Due to the invasive nature of this exposure, there is increasing consideration of the use of endovascular techniques in the repair of proximal axillo-subclavian injuries, with placement of a covered stent in an



18.19 Exposure of the brachial artery in the cubital fossa (left arm).⏎

emergency situation. Following stabilisation, a definitive repair with a vein bypass can always be performed at a later stage if clinically indicated.

The brachial artery may be approached with ease throughout its relatively superficial course. In the arm, exposure is by an incision along the medial edge of the biceps. The arm is abducted and rotated laterally and supported on an arm board (Figure 18.18). The deep fascia is divided along the same line, and care is taken to avoid the basilic vein, which pierces the deep fascia in this vicinity. The biceps muscle is mobilised and drawn laterally to expose the artery and the median nerve. For exposure at the elbow, the arm is abducted, externally rotated and supported on an arm board. The deep fascia (including the bicipital aponeurosis) is incised vertically and the bicipital tendon retracted laterally. This is illustrated in Figure 18.19 for the left arm. However, the vertical skin incision shown, across the flexor aspect of the joint, should be avoided by making a transverse cubital fossa skin crease incision, enlarged by vertical extensions, upwards from the medial end and downwards from the lateral end.

The overall management of vascular injuries is as described in previous sections, with identification of obvious and subtle signs. The presence of concomitant nerve injury is a relative indication for suspecting vascular injury, obtaining vascular imaging and proceeding with vascular repair. A few specific scenarios, such as subclavian artery injury associated with a first rib injury, have already been mentioned. Other specific scenarios are a supracondylar fracture of the humerus with a brachial artery injury or a more proximal fracture associated with an axillary artery injury. In children, a pink, pulseless hand in the setting of a supracondylar fracture may be managed with careful observation rather than immediate surgical intervention. Overall, the upper extremity is less prone to ischaemia; however, severe injury can lead to functional loss and amputation. Complex extremity injuries require assessment of the extent of soft tissue injury, early aggressive debridement and an appropriate soft tissue cover. This usually requires early involvement of a plastic surgery and/or a hand surgery specialist for the best outcomes.

Iatrogenic injury to these arteries during central line placement is also possible, although relatively rare given the number of lines now placed. If an injury is suspected at line placement, it is advised to leave the line in place and obtain contrast imaging through this and a concomitant CT angiogram to determine the track of the cannula. Removal alone can be considered for cannulas smaller than 4 French, with concomitant balloon control (through either peripheral or a femoral approach), placement of a covered stent, direct open repair and closure using a closure device.

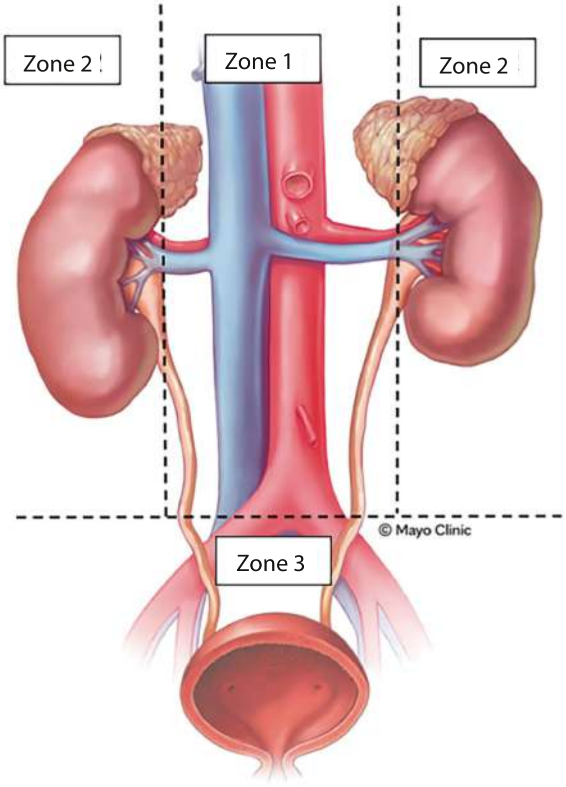
Venous injuries in the upper limb can usually be managed by ligation, but lateral venography should be considered, if feasible, especially in the proximal veins or junctional zone. Repair with a prosthetic graft can be an option in proximal upper extremity injury, where infectious complications are not as common as in the lower extremity. If the duration of ischaemia has been prolonged, elective fasciotomy should be considered.

CHEST, ABDOMEN AND PELVIS

Penetrating or blunt trauma resulting in major intracavitary vascular injury usually presents with the patients in hypovolaemic shock. This may be identified on a CT angiogram in a stable patient or as an abdominal haematoma during a trauma laparotomy. Injury to the heart, pulmonary vasculature and ascending aorta require a sternotomy, anterolateral thoracotomy or clamshell thoracotomy. These injuries are usually associated with high morbidity and mortality. Damage control resuscitation, placement of temporary intravascular shunts, REBOA and quick transfer to an OR, in preference to an emergency department laparotomy, are overall considerations, and have been discussed in other sections.

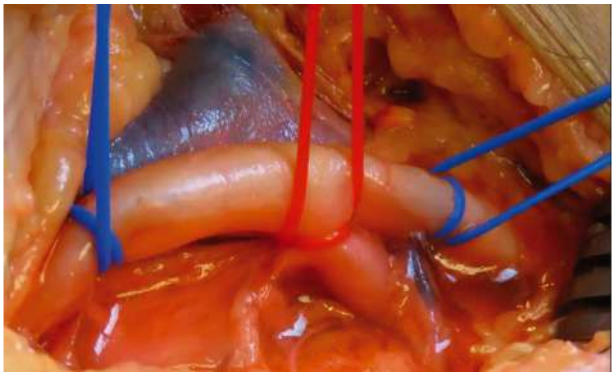
Blunt thoracic aortic injury (BTAI) occurs following acceleration–deceleration injury of the aorta (e.g. in motor vehicle collision). The most common location is at the aortic isthmus, distal to the origin of the left subclavian artery, followed by the ascending aorta, arch of aorta and descending aorta.[19] BTAI is traditionally classified, based on severity as per the Society for Vascular Surgery (SVS) grading system, into four categories: grade I, intimal tear; grade II, intramural haematoma; grade III, pseudoaneurysm; and grade IV, rupture.[20] Another classification system developed by Heneghan et al.[21] classifies BTAI into minimal, moderate and severe based on CT imaging. Minimal injuries require no intervention, moderate injuries are managed in a semi-elective manner and severe injuries require immediate repair.[21] Implementation of this approach has streamlined the treatment of BTAI with improved results, as highlighted by Quiroga et al.[22] Operative management of BTAI includes open repair with or without cardiopulmonary bypass, which requires a high posterolateral thoracotomy and is associated with high perioperative mortality and complications including paraplegia whenever aortic cross-clamping exceeds a threshold of 30 minutes. Thoracic endovascular aortic repair (TEVAR) obviates the need for thoracotomy, cardiopulmonary bypass and one-lung ventilation. TEVAR has been shown to be associated with better outcomes in multiple studies and has emerged as the preferred option for the management of BTAI.[23,24] Aortic endograft sizing is usually 1:1 with intravascular ultrasound utilised to appropriately size the underfilled aorta.

In the abdomen, vascular injury is usually associated with penetrating trauma, and the aorta, iliac vessels and renal arteries are the most commonly injured structures. Bleeding is usually retroperitoneal, and abdominal vascular injuries are divided into three anatomical zones (Figure 18.20). Zone 1, supra/inframesocolic, is a central retroperitoneal haematoma. Zone 1 injuries usually need exploration due to the high incidence of major vascular, pancreatic or duodenal injuries. Zone 2 involves flank haematomas. These need to be explored if expanding or when associated with penetrating injury. Zone 2 injuries can be managed conservatively if there is evidence on prior imaging confirming a lack of vascular injury. Zone 3 haematomas occur in the pelvis and exploration is not advisable. When associated with haemodynamic instability, following midline laparotomy, and four-quadrant packing, the supracoeliac aorta can be controlled; this can initially be with manual compression or compression using a sponge on a stick. However, rapid surgical control is usually essential. This can be achieved with control of the distal aorta, in the chest, through a thoracotomy. Additionally, in the abdomen, supracoeliac control is achieved by dividing the left triangular ligament of the liver, and to the lesser sac, identifying the left crus of the diaphragm, and protecting the oesophagus by palpation of a nasogastric tube, and pushing it away with a retractor or a suction device. This manoeuvre requires good lighting, with careful clamp placement, avoiding disruption of small phrenic arteries that may arise from this section of the aorta. Supracoeliac clamping should be kept to a minimum, as this leads to ischaemic bowel and hepatic injury with subsequent reperfusion injury.



18.20 Retroperitoneal vascular zones. (Used with permission of Mayo Foundation for Medical Education and Research, all rights reserved.) ⏎

Any ischaemic tissue below an aortic cross-clamp releases inflammatory cytokines, free radicals, activated white cells and other toxic metabolites into the circulation. These substances invoke a cascade of damage throughout the body, including myocardial depression and acute lung and kidney injury. Skilled intraoperative care, efficient surgery with a short ischaemia time and good postoperative intensive care facilities all improve results. Endovascular balloon control should be considered whenever feasible. Standard surgical manoeuvres are described for specific injuries. The Mattox manoeuvre, or medial visceral rotation of the left-sided organs, allows access to the supracoeliac aorta, coeliac artery, superior mesenteric artery, inferior mesenteric artery, and left renal and iliac vessels. The Cattell–Braasch, or extended Kocher, manoeuvre allows access to the infrahepatic vena cava, right renal vein, portal system and right iliac vessels through right-sided medial visceral rotation. A standard midline inframesocolic retroperitoneal approach involves superior retraction of the transverse colon and midline division of the retroperitoneum. Reflexion of the peritoneal attachments lateral to the caecum, and sigmoid, can be used for exposure of the iliac arteries.



18.21 The superficial femoral artery is identified and controlled, with control of the profunda achieved by 'exclusion'. (Used with permission of Mayo Foundation for Medical Education and Research, all rights reserved.) ⏎

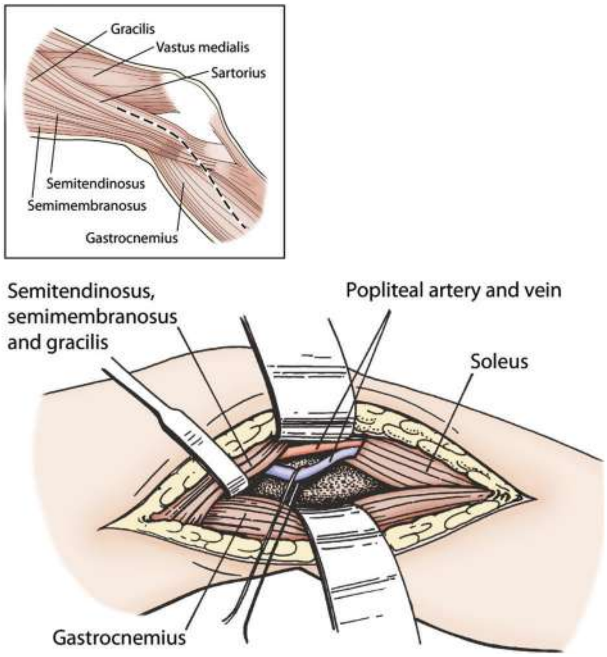
LOWER EXTREMITY

The common femoral artery commences as a direct continuation of the external iliac artery emerging from under the inguinal ligament at the mid-inguinal point. It runs obliquely downwards through the femoral triangle, with its bifurcation usually 3–4 cm below the inguinal ligament. The superficial femoral artery is the direct continuation of the common femoral artery. It runs within the subsartorial canal, becoming the popliteal artery distally as it passes through the adductor hiatus. The profunda femoris artery (or deep femoral artery) is the other major branch arising from the posterolateral side of the femoral artery; it runs deep to the superficial femoral artery to disappear between the adductor muscles. At the inguinal ligament, the femoral nerve lies lateral to the artery and the femoral vein is medial. Distally, the femoral vein lies posterior to the artery.

Exposure

Exposure is obtained through a vertical incision over the femoral artery. The inguinal ligament is identified, with identification of the common femoral artery at the midpoint of the ligament. The profunda is usually a posterolateral branch, but the branching pattern may vary. The superficial femoral artery is identified and controlled, with control of the profunda achieved by 'exclusion' (Figure 18.21). At the groin, this exposure involves staying medial to the sartorius. To expose the distal superficial femoral vessels, sartorius is retracted medially and the underlying bridge of fibrous tissue, which covers the subsartorial canal, can be divided.

The popliteal artery begins as a continuation of the superficial femoral artery at the adductor hiatus. It runs down through the popliteal fossa to end at the lower border of the popliteus by dividing into the anterior tibial artery and the tibio-peroneal trunk. The latter divides into the posterior tibial and peroneal branches. The popliteal vein (which is often a pair of veins) is medial to the artery in its lower part but crosses the artery posteriorly to lie posterolateral to the artery in its upper part. The tibial nerve crosses the vessels posteriorly, from the lateral to medial sides, as it travels down the popliteal fossa.



18.22 Exposure of the lower left popliteal artery: medial approach. Only the lower half of the illustrated skin incision has been used, and the tendinous insertions into the proximal tibia are preserved and retracted anteriorly. ⏎

Exposure to the popliteal artery is obtained by an incision above and below the knee, which can be joined to run across the knee in cases of need (e.g. in an obese patient with a limited behind-knee popliteal arterial or venous injury) (Figure 18.22). The tendons of sartorius, gracilis and semitendinosus, which all cross the operative field, can be divided and repaired at the end of the operation.

COMPLICATIONS, POSTOPERATIVE MANAGEMENT AND SURVEILLANCE

Compartment syndrome occurs most commonly following a crush injury or reperfusion following delayed treatment of ischaemia. Both processes lead to swelling of muscle in their respective fascial compartments impeding venous return initially and subsequently arterial inflow. A high degree of clinical suspicion, pre-emptive fasciotomy and early detection of features of impending compartment syndrome, supplemented by measurement of compartment pressures if available, is essential to prevent irreversible tissue damage. Key early features of compartment syndrome are pain that is out of proportion to the injury and paraesthesia of the skin.[25,26] Pain on passive stretch of the affected muscles, tense compartments on palpation, pallor and sensorimotor deficits are some of the common physical findings. The anterior compartment of the lower extremity is the most vulnerable. Fasciotomy to relieve pressure within the affected compartment is the definitive management of compartment syndrome and should be performed early or pre-emptively if there has been ischaemia for greater than 6 hours. Delayed fasciotomy is associated with an increased risk of complications such as limb ischaemia, local infection and the need for amputation.[27] Suspicion of an impending compartment syndrome in an obtunded patient should prompt evaluation of intracompartmental pressure. Serial monitoring is needed, as earlier measurements could be normal. The normal pressure within a muscle compartment ranges from 0 to 8 mmHg.[28] A difference between diastolic blood pressure and intracompartment pressure of 20–30 mmHg is used as a threshold for diagnosing compartment syndrome.[29] Management also includes the removal of all external pressure, elevating the limb above the level of the heart and compression wraps to improve venous return.[30] The gluteal muscles, arm, forearm, hand, thigh and foot can all be affected.

INFECTION

Perioperative antibiotic administration at appropriate intervals is critical in patients with vascular injury. Postoperative wound infection occurred in about 3.7% of all vascular injuries in the extremities in a large case series of wartime vascular injuries.[31] Risk factors associated with postoperative wound infection include contamination of the operative field, wound desiccation, usage of prosthetic graft compared with an autologous vein graft, and formation of fistulas involving the injured vessel and the intestines. An endovascular approach, wherever feasible, has a lower rate of surgical site infection than an open approach.[32,33] Strategies for the prevention of surgical site infection include optimal wound care, prevention of wound desiccation by providing adequate tissue coverage, the use of autologous vein graft and endovascular techniques, wherever feasible. Once infection has occurred, adequate debridement should be performed along with appropriate antibiotic cover.

THROMBOSIS/EMBOLISM

Following vascular repair, it is important to monitor for clinical signs of re-thrombosis by serial clinical monitoring and duplex ultrasound, or CT angiography, whenever there is clinical suspicion of such an event. Management includes surgical re-exploration and thrombectomy. However, thrombosis or embolism can be reduced with appropriate antiplatelet and anticoagulant usage.

PSEUDOANEURYSM/ARTERIOVENOUS FISTULA

Pseudoaneurysm can occur at the site of an initial vascular injury or at the site of an anastomosis. Pseudoaneurysm can also occur following peripheral endovascular procedures, and usually at the access site, with incidence rates of around 3%.[34] Risk factors include older age, female patients, periprocedural antithrombotic use and not using vascular closure devices.[34] In the peripheries, a pseudoaneurysm can be diagnosed with a duplex ultrasound. The duplex reveals the location and size of the defect in the artery, the length and diameter of the neck of the pseudoaneurysm, and the presence of fistulisation into surrounding structures. Ultrasound-guided compression can be used to treat a small pseudoaneurysm. Thrombin injection is the first line of management. Non-resolution, late presentation, large pseudoaneurysms with a wide neck and the presence of significant compressive symptoms require further investigation with a CT angiogram. Open and endovascular repair are feasible, depending on the location and clinical presentation.[35]

WOUND CARE, REHABILITATION AND ANTITHROMBOTIC THERAPY

Adequate soft tissue cover is essential over repaired vessels to prevent desiccation, disruption and infection. Wounds without adequate skin closure should be managed with negative pressure dressings if available.[36] Rehabilitation should be started as soon as possible after repair of an extremity vascular injury to prevent contractures and loss of sensorimotor function. Rehabilitation can be an intricate and prolonged process in upper limb injuries. The goal of rehabilitation should factor in the economic resources and level of pre-injury activity of the patient. Patients are usually initiated on antiplatelet medication (low-dose aspirin clopidogrel), once the bleeding risk is minimised, after an arterial repair or a bypass. The presence of more widespread thrombosis or embolism, or other clinical factors, may require additional use of anticoagulants. The surveillance following vascular repair is clinical assessment with additional non-invasive vascular laboratory studies or duplex for extremity trauma, and CT angiography for thoracic or abdominal vascular repair. Surveillance is usually performed every 3–6 months for the first year, following which the frequency can be reduced. Some situations, such as placement of a TEVAR for BTAI, will require lifelong surveillance. Late complications such as endoleaks, graft infection, pseudoaneurysm formation, graft stenosis or occlusion can occur. A detailed discussion about the management of these situations is beyond the scope of this chapter.

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Operative management of vascular disease for the general surgeon

19

Edwin Stephen and Vimalin Samuel

VASCULAR PATHOLOGY

The spectrum

The range of pathology that a vascular surgeon sees and manages has increased over the past decade. The diseases include varicose veins, venous and non-healing ulcers, arterial aneurysmal disease, atherosclerotic occlusive arterial disease, embolic events and vasculitis, diabetic foot, deep vein thrombosis, extracranial carotid artery disease, carotid body tumours and paraganglioma, thoracic outlet syndrome, lymphoedema and vascular malformations. Vascular surgeons also deal with arteriovenous access creation and maintenance of patency, and collaborate with oncological surgeons in extending the boundaries of excision and reconstruction of the arterial and venous systems. Additionally, the skill set of vascular surgeons has grown to include the ability to perform endovascular procedures. The most common pathology seen by vascular surgeons varies depending on their geographical location, interest and expertise.

Aneurysms

Aneurysms can be divided into true aneurysms, in which all three layers of the arterial wall are dilated but in continuity, and false aneurysms, in which there is a breach in the layers and rupture is prevented by thrombus, a single intact layer and the surrounding tissues. False aneurysms (also called pseudoaneurysms) may result from trauma or infection, although the most common cause is iatrogenic injury. The aorta and the iliac, common femoral, popliteal and common carotid arteries are the most common extracranial arteries to be affected by true aneurysms. The discovery of an aneurysm in a patient is often incidental at clinical examination or, more commonly, in an investigation for another reason, or through a targeted aneurysm screening initiative. Symptomatic aneurysm may present as a mass, a pulsation or a feeling of pressure from the expanding aneurysm. True aneurysms are saccular, or fusiform, in shape and the treatment urgency is dictated by their size and shape. Unfortunately, complications such as rupture, thrombosis, distal embolism, fistula formation or infection still occur and can be the mode of presentation. However, these emergency presentations are not as common in more developed healthcare systems with screening programmes and increased use of radiological imaging in patient care.

Occlusive disease

The prevalence, and incidence, of asymptomatic lower limb peripheral arterial disease (PAD) as per the Global Peripheral Artery Disease Study Occlusive was estimated to be 237 million cases worldwide in 2015, a relative increase of 17% from 2010. The prevalence has risen sharply in low- and middle-income countries (22.6% relative increase vs 4.5% in high-income countries).[1] PAD may present with moderate symptoms of insidious onset, at one end of the spectrum, ranging to a dramatic symptomatic deterioration producing acute or critical ischaemia, at the other end. This variation can range from 5% progression over 5 years to 21% becoming symptomatic within a year and may be, in part, attributed to low public awareness and poor risk factor control as people age.[1] Many patients do not notice any symptoms until more than one segment is affected or long occlusions have developed, such is the compensatory capacity of a well-developed collateral arterial system. Atherosclerosis is the most common aetiology. Mortality rates range from 13% to 50% at 5 years in this subset.[1] Most interventions are for lower limb arterial occlusions, but a vascular surgeon will also be required to treat occlusive arterial disease of the upper limb, the extracranial carotid circulation, the kidneys and the gut. Coronary artery disease, cerebrovascular disease and chronic kidney disease coexist in patients with PAD in 25–70%, 14–19% and 10–23% of cases, respectively. Patients with PAD have more extensive, calcified and progressive coronary

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atherosclerosis.[1] This coexistence of disease is an indication for routine pharmacological secondary prevention with antiplatelet and statin therapy.

Embolic disease

An embolus presents as a sudden arterial event, with the effect depending on the size and site of the embolus and the presence of an adequate collateral circulation. These collaterals may be normal anatomical pathways serving the same tissue bed (e.g. the radial and ulnar vessels) or anastomotic channels that have enlarged secondary to coexistent chronic occlusive disease. Large emboli can arise from the left atrium in patients with atrial fibrillation or from the left ventricle in association with a ventricular aneurysm or a myocardial infarction. Emboli can also arise from the thrombus within an aneurysm in a more proximal part of the arterial tree. Atheromatous emboli from an unstable atheromatous plaque are usually smaller and often multiple, but their highly thrombogenic nature results in damage greater than expected for their size. Acute limb ischaemia secondary to emboli needs urgent assessment, appropriate intervention based on the grade of ischaemia and follow-up.

Diabetic foot Diabetes is considered by many international organisations as a public health emergency and is estimated to affect 1 in 11 adults. Diabetic foot complications account for most minor and major amputations all over the world. About 50% of patients with diabetes and foot ulcers have underlying PAD, and diabetes increases the major adverse limb and cardiovascular events.[2,3]

Paraganglioma: Carotid body tumour and schwannoma General surgeons, head and neck surgeons and vascular surgeons are seeing increasing cases of a swelling in the carotid triangle due to increasing awareness among colleagues and an increase in imaging. The most common paraganglioma is a carotid body tumour, followed closely by schwannoma, glomus tumour and lymphoma. Carotid body tumours can be very vascular and, when mistaken for a lymph node, the bleeding encountered at biopsy or attempted excision could terrify and unnerve most surgeons.[4]

Vascular trauma

Vascular trauma includes iatrogenic vascular injury and the injuries sustained in a range of situations, including military conflict and civilian violence. The relative importance of the various aetiologies will depend on the environment within which a surgeon practises. Vascular trauma includes puncture injuries, crush, thrombosis *in situ* and dissection related to both penetrating and non-penetrating trauma. Vascular trauma is discussed in Chapter 18.

Vascular malformations The prevalence of extracranial vascular malformations has been estimated to be from 0.1% to 1% of the population. The cases in order of decreasing prevalence are venous, venolymphatic, slow flow, lymphatic, Klippel–Trenaunay syndrome and arteriovenous malformations.[5,6] Management of malformations can vary from conservative symptom-based management to intervention that includes sclerotherapy and/or excision.

Arteriovenous access End-stage kidney disease has increased in incidence in East and South East Asia, as has global prevalence. This has been attributed to increasing survival of this subset of patients and the availability of haemodialysis units in developing economies.[6] An arteriovenous fistula (AVF) for haemodialysis is created by nephrologists, urologists and general/transplant/vascular surgeons. Complications arising from creating these fistulas include, among others, stenosis, pseudoaneurysms, blowout of the anastomosis and vascular steal syndrome. Management is by a combination of endovascular techniques and open surgery where needed.

VENOUS DISEASE

Varicose veins are incompetent, elongated, tortuous and dilated superficial veins (a varix is a localised aneurysmal dilatation of a vein). The condition is caused by valvular dysfunction, resulting in venous reflux with a subsequent increase in ambulatory pressure in the venous system. Varicose vein surgery is widely performed for ill-defined and quite varied symptoms and signs. Patients have the option of endovenous and open surgery, with the latter considered as the standard of care when available. Surgery is associated with higher recurrence rates and modest patient satisfaction. However, patient demand for the treatment of varicose veins is high and careful selection is imperative. Patients present with a spectrum of symptoms ranging from purely cosmetic concerns through to the skin changes of chronic venous insufficiency and ulceration. Patients with venous insufficiency and venous ulceration have the most to gain from surgery on the superficial venous system.

Deep venous thrombosis is common, and the consequences are wide and varied. The natural history of adequately treated deep venous thrombosis is generally complete thrombus resolution with minimal long-term symptoms. However, other complications, such as pulmonary emboli, are life-threatening emergencies. In addition, chronic venous ulcer disease is a highly morbid condition. The rare venous claudication from a chronically obstructed system can be incapacitating. Venous gangrene, resulting from massive occluding proximal thrombosis, is also rare. Incipient venous gangrene can be managed by aggressive leg elevation with the salvage options of thrombolysis or surgical thrombectomy.

Medico-legal claims are not uncommon in the field of vascular surgery. Improvement in surgeon–patient communication, the consenting process and skill sets can, and has, led to lesser litigation.[7]

SUPERFICIAL VEIN DISEASE

As regards varicose veins, 80% originate from the great saphenous vein (GSV). The remaining 20% originate from the short saphenous vein (SSV). The proportion of limbs demonstrating incompetent calf perforating veins and deep venous or SSV reflux increases as the clinical status deteriorates.[8] Over one-third of patients with a leg ulcer will have SSV disease. Careful preoperative assessment with the patient in the standing position is therefore essential. It is also important to ask about changes in bowel/bladder function and any changes in menstrual history in women that may trigger suspicion of a pelvic pathology causing or exacerbating venous pathology of the lower limb. The abdomen should be examined for any masses, and the peripheral pulses should be palpated. A pragmatic, resource-conscious approach is to perform a venous duplex on patients with chronic venous insufficiency varicose veins: oedema, skin changes, impending ulcer, active or healed ulcer, recurrent varicosities and varices of ambiguous distribution. Duplex scanning is not recommended for cosmesis, spider veins or telangiectasia.

Duplex scanning is non-invasive and provides both anatomical and physiological information on venous pathology, but it is operator dependent. Venous duplex is recommended as mandatory (where available) on patients before varicose vein surgery (as is a pelvic ultrasound in women) and should be performed with the patient standing.

ANATOMY

The GSV commences as a confluence of vessels on the medial aspect of the foot and lies on the medial aspect of the limb in the subcutaneous fat until its termination at the saphenofemoral junction (SFJ). It passes in front of the medial malleolus at the ankle, but behind the femoral condyle at the knee. Superficial tributaries, and connections with the short saphenous system, are variable (Giacomini vein). There are three named tributaries that drain into the SFJ, namely the superficial epigastric, circumflex and pudendal veins. Besides this there are connections with the deep venous system via *perforator veins* that perforate the deep fascia. In the thigh, the perforators connect the GSV with the deep veins, but in the calf the perforators mainly connect the deep veins with the posterior arcuate tributary of the GSV (Figure 19.1).

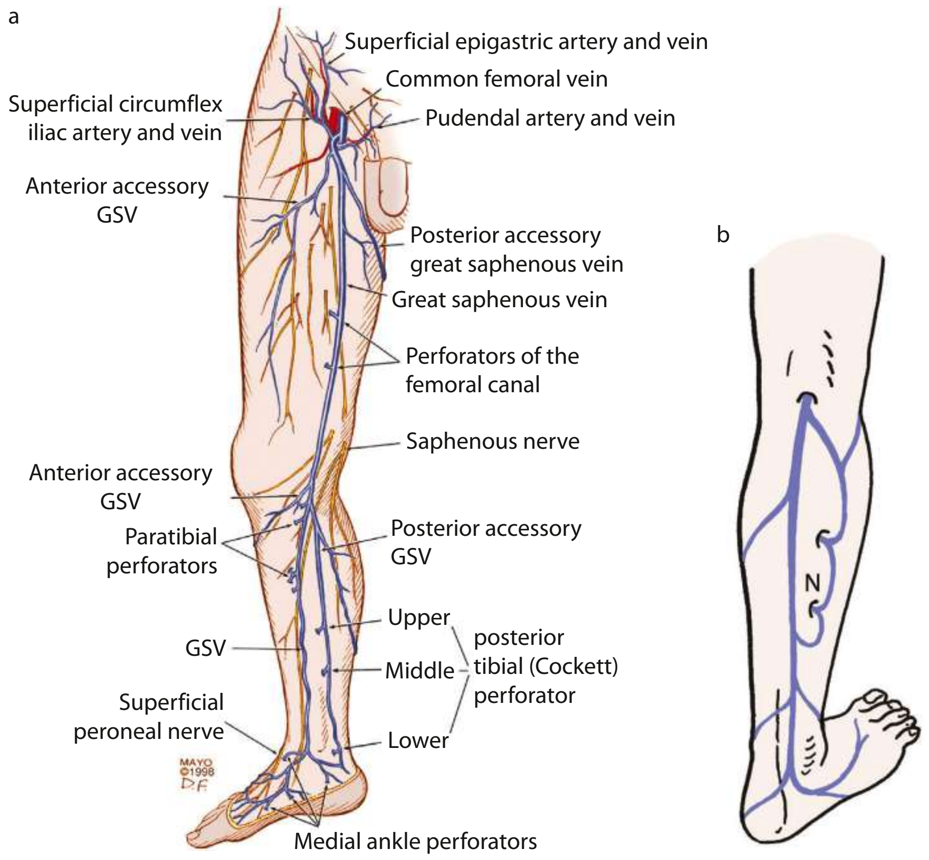
The SSV is formed on the lateral side of the foot. It ascends behind the lateral malleolus and lies on the lateral, and then the posterior, aspect of the leg until its termination at the saphenopopliteal junction (SPJ). The vein pierces the dense deep fascia of the popliteal fossa at a variable point from the upper mid-calf to just above the skin crease behind the knee. The SPJ is also variable in position, as is the length of vein lying beneath the fascia. This anatomical variation is in itself a strong indication for routine duplex scanning prior to SSV intervention.

SFJ LIGATION, STRIPPING THE LONG SAPHENOUS VEIN AND PHLEBECTOMIES

This procedure is also referred to as Trendelenburg stripping and stab avulsions or high tie stripping and stab avulsions. Varicosities that need to be avulsed or sclerosed should be marked preoperatively with a permanent marker, with the patient standing. It helps to have the patient walk about for a few minutes before marking to help the veins stand out. Once marked, ask the patient to point out any veins you may have missed and mark them too.

Regional or general anaesthesia can be used depending on the comfort of the surgical team, availability and patient choice. The patient is positioned supine with the hip slightly flexed, abducted and externally rotated. If one has access to an ultrasound machine, mark the SFJ. If not, palpate the femoral artery below the inguinal ligament and mark a point that is one finger breadth medial to this and another that is two finger breadths lateral to this point. Make a horizontal incision along, or just below, the groin crease joining these two points. In obese patients, the skin crease may be misleadingly lower and it is often affected by intertrigo, increasing the risk of infection. The incision is deepened through the subcutaneous fat and then through a clear layer of superficial fascia (Scarpa's fascia). The deep venous system lies in the fat deep to this layer. Langenbeck retractors applied just below Scarpa's fascia to the upper and lower flaps open the fat and one can see the superficial epigastric vein, which will lead you to the SFJ. A correctly placed incision will expose the SFJ, which should be cleared proximally and distally using sharp scissor dissection until the anatomy is revealed and the tributaries are defined (Figure 19.2).

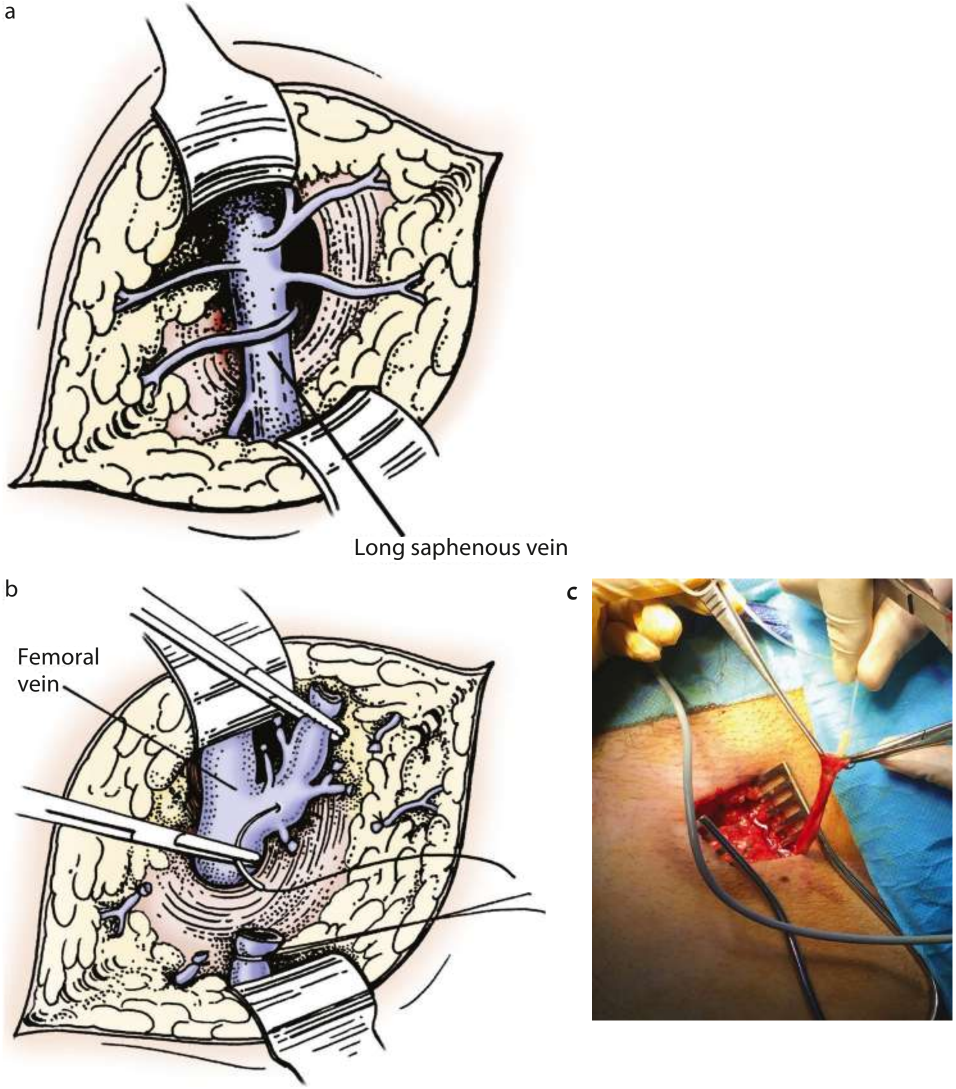
The presumed GSV must not be divided until the anatomy has been unequivocally confirmed. The


a
Superficial epigastric artery and vein
Common femoral vein
Superficial circumflex iliac artery and vein
Pudendal artery and vein
Anterior accessory GSV
Posterior accessory great saphenous vein
Great saphenous vein
Perforators of the femoral canal
Saphenous nerve
Anterior accessory GSV
Paratibial perforators
Posterior accessory GSV
Upper
Middle
Lower
posterior tibial (Cockett) perforator
GSV
Superficial peroneal nerve
MAYO ©1998 D.F.
Medial ankle perforators
b
N

19.1 The anatomy of superficial veins is very variable except for the main great and short saphenous trunks. The thigh perforators communicate directly with the GSV. Below the knee the perforators labelled 'Cockett' and N communicate only with tributaries of the main trunks. (a, From Gloviczki et al.[9] Reproduced with permission.) ⏎

common femoral vein must be clearly identified, continuing both proximally and distally in a deeper plane to the presumed SFJ. The common femoral vein is usually a different colour from the GSV. There is also a 'whitish' ring at the junction, which is due to more circular smooth muscle fibres than the GSV or common femoral vein wall. The external pudendal artery usually, but not invariably, crosses transversely between the two veins and may be ligated if necessary. The medial and lateral sides of the common femoral vein should be sufficiently exposed to confirm both the anatomy and the presence of unnamed tributaries that may cause recurrences and, according to some authorities, the vulval varices. These are ligated and/or divided. In the absence of vulval varices, and in premenopausal women, the medially placed superficial external pudendal vein can be left open and has been considered to reduce dysmenorrhoea and pelvic congestion syndrome. The three named tributaries to the SFJ, and the proximal GSV, are then ligated and divided. Dividing the tributaries at their first confluence may make recurrence from the formation of collateral channels less likely than if the ligated tributaries are lying near the saphenous stump, although this is unproven. It is worth ligating and dividing the posteromedial vein, which joins the GSV about 3–5 cm from the SFJ. This reduces postoperative groin haematoma. The GSV is then divided between a right-angle clamp placed just above the SFJ and an artery clamp on the GSV (as distal as possible). The stump is best suture ligated in such a way that there is no narrowing of the common femoral vein (Figure 19.2b). Narrowing this vessel with a suture placed too deep or leaving an overly long stump of GSV may increase the risk of deep venous thrombosis.

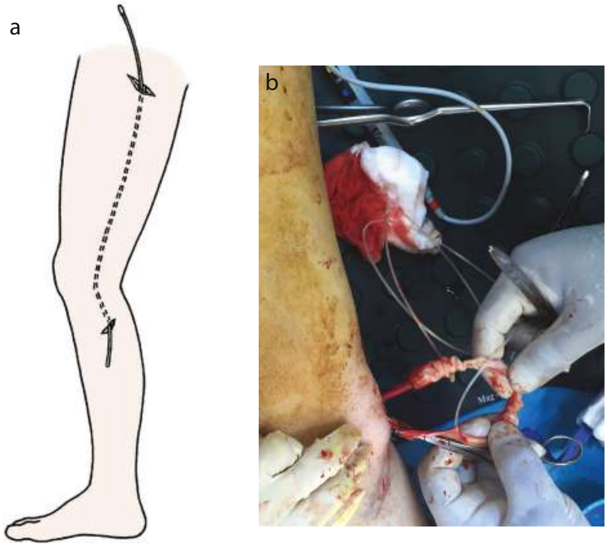
The vein stripper is then passed down the GSV to the distal thigh/just below the knee joint. Passing an artery clamp distally before inserting the stripper breaks the proximal valve and enables smooth passage of the stripper (Figure 19.2c). The divided distal end of the GSV should be firmly tied over the stripper, allowing it to fall into the wound, without a 'head'. Leaving the suture long enables the stripper or vein to be retrieved in case they slip while passing the stripper distally. The stripper can get stuck at the level of the mid-thigh due to a large perforator. The thigh should be picked up on either side of the stripper and renegotiated. The stripper should remain



19.2 Saphenofemoral ligation. (a) The terminal few centimetres of the GSV and its tributaries are exposed. The tributaries are ligated and divided. The proximal end of the GSV is lifted forwards to display the SFJ and any remaining tributaries. (b) The GSV is then transfixed with a very short stump near the femoral vein. (c) Finally, the vein stripper is passed cranio-caudal up to just above/below the knee. ⏎

palpable throughout its course, confirming that it has remained in the superficial veins and not traversed a perforator into the deep system. Stripping below the knee increases the risk of damage to the great saphenous nerve, and leaving the GSV *in situ* in the thigh increases the rate of recurrence of varicose veins. The stripper is retrieved through a short longitudinal incision (Figure 19.3a). The vein may tear as the stripper is retrieved. If the vein is intact, a small venotomy is made and the tip of the stripper is delivered. The stripper is then pulled down, inverting the vein, which will also avulse the tributaries and perforators. Bleeding can be reduced by placing the patient in the Trendelenburg position a few minutes prior to stripping if the entire operation has not been performed in Trendelenburg. Stripping techniques that invaginate the vein are gaining popularity, as they cause less trauma to adjacent tissue (Figure 19.3b), although some surgeons still utilise the head supplied with the stripper.

Pre-marked varices are then avulsed through a series of small longitudinal stab incisions made with an 11-blade knife. If there are many phlebectomies to be performed, delivery of the stripper and vein should be postponed until phlebectomies have been completed to minimise bleeding and subsequent bruising. Care should be taken when performing phlebectomies on the lateral aspect of the leg, in the region of the fibular head, as the common peroneal nerve is nearby and may get injured or avulsed. If Steri-Strips are available, then the stab incisions should be approximated with Steri-Strips. Sterile gauze should be applied over



19.3 (a) The subcutaneous route of the stripper in the GSV is shown with a dotted line. (b) Removal of the stripper just below the knee and inversion stripping of the GSV. ⏎

any oozing sites with an overlying sterile cotton roll and, finally, an Elastocrepe bandage should be applied firmly up to the proximal thigh. A broad adhesive to the crepe bandage edge in the thigh (half on the bandage and half on the skin) will prevent the bandage from rolling down. If the varices are large and multiple, patients may need staged avulsions, as blood loss can be significant.

Significant venous bleeding may occur during a varicose vein operation, caused by a tear to a major tributary or partial avulsion of a tributary from the common femoral vein. An anxious surgeon must avoid the temptation to apply artery forceps blindly, thereby damaging the femoral vein or even the femoral artery. The appropriate first steps are firm pressure with a gauze swab and reduction of venous pressure by lowering the head of the table. It is important before assessing the damage to inform the rest of the theatre team of the situation so that the availability of suction equipment is ensured and the anaesthetist can secure appropriate venous access. If the damage is reassessed after a 5-minute delay, often the bleeding will have ceased and accurate application of vascular clamps or artery forceps to a vessel, or the repair of a femoral vein tear, will be easier. If there is still a major problem, blood should be cross-matched, assistance should be summoned and the incision should be enlarged before attempting definitive repair.

GROIN SURGERY FOR RECURRENT VARICOSE VEINS

Surgery for recurrent varicose veins is associated with significantly greater morbidity and worse patient satisfaction and outcome than varicose vein surgery in an unoperated groin. Recurrence associated with reflux from the groin results either from incomplete SFJ disconnection at the original operation or from neo-vascularisation resulting in new connections between the common femoral vein and a GSV that was not stripped but left *in situ* in the thigh.[10] Recurrence can also occur through a mid-thigh perforator with reflux into a persistent GSV. Preoperative imaging by duplex scanning is essential and, in some cases, intravascular ultrasound.

If significant reflux is demonstrated at the groin, then re-exploration of the groin may be considered, preferably by a vascular surgeon. The skin incision is preferably made after marking the junction with ultrasound. The incision should be started from an unscarred area, dissecting carefully towards the common femoral artery. Dissection should be medial to the common femoral artery to define an unscarred tissue plane at the level of the common femoral vein above and below the connection to the superficial system. Neo-vascularisation veins should be avoided, as these vessels are thin walled and difficult to dissect. Having defined the common femoral vein above and below the SFJ, all of the anterior tissue can be isolated. The scarred tissue, with thin-walled veins, at the junction itself is left until last and is then finally ligated and divided. In recurrent groin surgery for varicose veins, the GSV should be stripped if this was not done at the original operation.

If the groin component is trivial, especially if the GSV is fed by a mid-thigh perforator, stripping from the level of the knee up as far as possible, without re-exploring the groin, can minimise morbidity. The stripper can be retrieved below the previous skin incision and any proximal stump ligated.

Short saphenous vein ligation

The position of the SPJ is very variable. The upper portion of the SSV is not easily palpable after it has pierced the fascia. It is important to mark the vein, and its termination, preoperatively by venous duplex scanning. The patient is best positioned prone, which has implications for the anaesthetic and nursing teams.

Once the patient is in position, a rolled sheet is placed under the ankle and anterior to the tibia to flex the knee. A transverse skin incision is made over the vein about 2 cm below its termination. The vein may be seen through the deep fascia. The deep fascia is then divided. The vein is dissected until artery forceps can be passed deep to it, with care taken to avoid damaging the accompanying, and often adherent, sural nerve. The vein is divided between right-angle forceps and artery forceps, and the distal end is ligated. The proximal end is then followed deep into the popliteal fat. The finding of multiple tributaries from muscle outlines the proximity of the SPJ. These tributaries are easy to tear, and tying them off is time consuming and often difficult. Ligation of the SSV just short of the junction is satisfactory in most cases. In addition, the SPJ is not always a distinct T-junction, as found in the groin, and the vein may terminate among a plexus of thin-walled deep veins. Overzealous dissection may damage these, with resultant haemorrhage, which is difficult to control, putting at risk the artery and tibial nerve. However, there is frequently a superior tributary to the last centimetre of the SSV. This tributary is the termination of a superficial vein that may also communicate with the GSV. It is important to ligate and divide this potential source of recurrence.

The fascia is then closed with an absorbable suture before closure of the subcutaneous tissue and skin. It is not uncommon for patients to complain of a bulge seen, or felt, postoperatively and it is worthwhile mentioning this while consenting for surgery.

There is great anatomical variation of the SSV system. The SSV may enter the popliteal vein well above the popliteal skin crease and, on occasion, an incompetent SSV may have no communication with the popliteal vein. The superior branch may be so large that it appears as a continuation of the main vein with only a short side communication between superficial and deep veins at the level of the popliteal skin crease. This variant must be considered, as it can be damaged by rough passage of an instrument deep to the SSV, especially if the preoperative marking has been misleading.

The authors prefer an endovenous option to treat the SPJ incompetence. If using a thermal ablation technique, then care should be taken to have adequate tumescence around the sural nerve to reduce postoperative numbness.

Perforating veins

A thigh strip will avulse significant thigh perforators. Perforating veins in the calf do not join the GSV directly, and stripping of the main vein to the ankle does not treat them (see Figure 19.1). Direct surgery for incompetent calf perforators is best performed by a subfascial endoscopic approach. There are usually severe skin changes in the area and incisions directly over the vessels are unlikely to heal satisfactorily. An incision through healthy, more proximal, skin and deep fascia allows access to the plane between the muscle and deep fascia. The perforating veins crossing this plane can be ligated and divided. However, many incompetent perforators return to normal function with superficial surgery alone.[11]

The current literature does not support the treatment of perforators for Clinical, Etiological, Anatomical and Pathophysiological (CEAP) class 2 and 3 patients. The treatment of pathological perforators with thermal ablation has better thrombosis and occlusion rates than with ultrasound-guided foam sclerotherapy and can be offered to patients with non-healing venous ulcers, after superficial reflux and compression therapy has failed.[12]

Minimally invasive venous surgery

The surgical management of varicose veins has evolved in recent years and many would now advocate minimally invasive endovenous intervention.[5] One major advantage of these techniques is the avoidance of general anaesthesia, with the procedures being performed using tumescent local anaesthetic infiltrated around the GSV under ultrasound guidance. All three endovenous techniques (endovenous laser therapy, radiofrequency ablation and foam sclerotherapy) cause injury to the vessels and rely on subsequent thrombosis and long-term occlusion following a short period of compression. The vein is cannulated at, or below, the level of the knee under venous duplex guidance using the Seldinger technique. The probe or catheter is then passed up to the SFJ and then gradually withdrawn, applying heat, light or chemicals to damage the vein. The tumescence around the vein is vital as a heat sink to prevent thermal damage to the skin. Foam sclerotherapy may be used to manage minor calf and thigh varices.

Minimally invasive venous surgery reduces post-procedural discomfort and may allow a more rapid return to function compared with open surgical intervention. The long-term results appear equivalent to those of open surgery.

Endovenous options

These options are dependent on the expertise and equipment available, with ultrasound-guided foam sclerotherapy being the most cost-effective and arguably having the highest recurrence rate in this category of treatment. Therefore, it is more popular for treating spider veins/telangiectasia or in combination with other modalities.

The commonly used tumescence-based options include endovenous laser and radiofrequency ablation. The non-thermal, non-tumescence options are glue or foam with scarring of the vein from within. High-intensity focused ultrasound (HIFU) is a new modality that is completely non-invasive and causes less discomfort, but it is expensive. The results of a long-term follow-up are awaited.

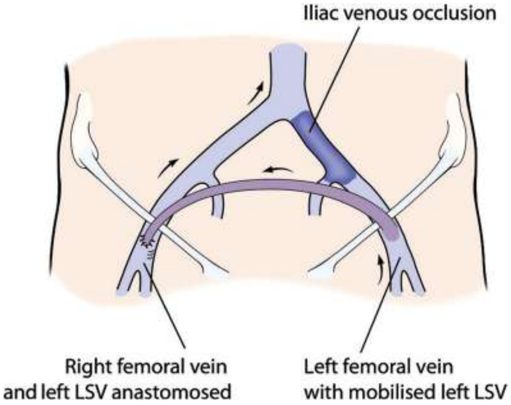
COMPLICATIONS OF SUPERFICIAL VENOUS SURGERY

Litigation is common after unsatisfactory outcomes following varicose vein surgery, so prior to embarking on surgical intervention it is important that patient expectations are managed and potential complications are explained. Potential complications include the significant risk of wound infection (higher for repeat groin surgery), peripheral nerve injury (resulting most commonly in sensory loss in the distribution of either the saphenous nerve or the sural nerve), deep venous thrombosis, thermal injury/burn and recurrence.

The following YouTube video can be used to watch the steps in open and endovenous varicose vein surgery:

SAPHENOUS CROSSOVER GRAFT (PALMA PROCEDURE)

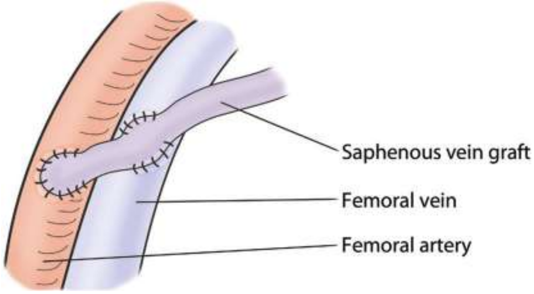
This bypass procedure can restore venous drainage when there is a unilateral iliac vein occlusion. Although only a minority of patients with chronic venous insufficiency have an isolated occlusion at this level, these patients may have particularly severe symptoms, including incapacitating venous claudication. The GSV on the contralateral side is used as the bypass. The GSV is mobilised from groin to knee (preferably with a diameter of 5 mm and more) and divided distally, but the SFJ is left intact. In addition, the tributaries around the junction are preserved to maintain the normal alignment of the vein and prevent kinking. The femoral vein on the opposite limb is exposed in readiness to receive the vein graft. A suprapubic subcutaneous tunnel is created through which the vein graft is passed. An end-to-side anastomosis is then performed (Figure 19.4). The reported patency is 70% at 3- to 7-year follow-up.[13]


Iliac venous occlusion
Right femoral vein and left LSV anastomosed
Left femoral vein with mobilised left LSV

19.4 A Palma crossover vein graft for an occluded left common iliac vein. The left GSV has been brought across for an end-to-side anastomosis onto the right femoral vein. LSV, long saphenous vein. ⏎

Temporary arteriovenous fistula

This addition to the procedure described above is favoured by some surgeons to increase flow through the graft in the early postoperative period when the danger of thrombosis and graft occlusion is highest. Once this period is over, the AVF is closed by radiological intervention. A separate vein, prosthetic graft or the end of the GSV (as illustrated in Figure 19.5) can be used to create the AVF.



19.5 An AVF has been created by anastomosing the vein graft onto both the common femoral vein and the common femoral artery. ⏎

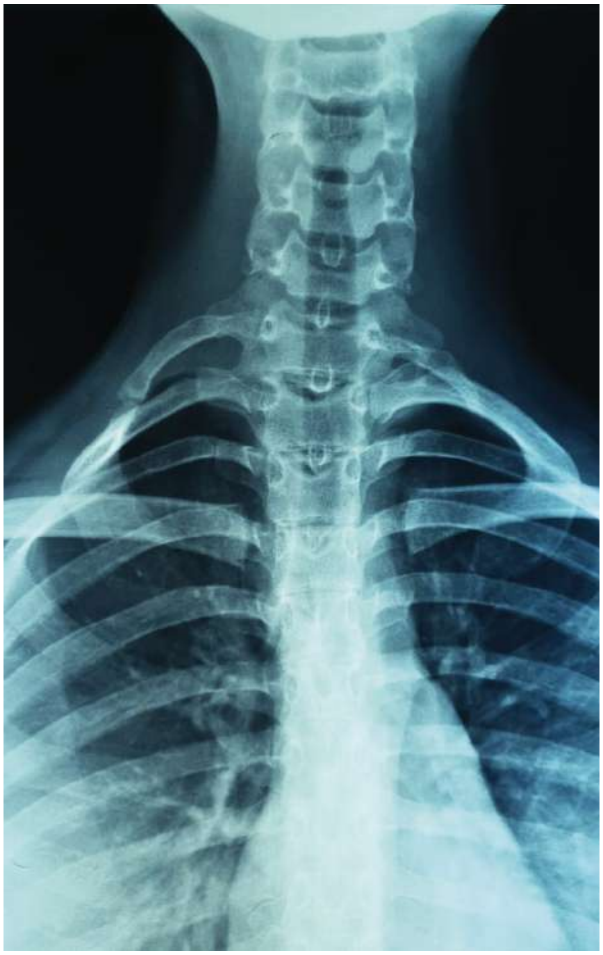
THORACIC OUTLET SYNDROME

The neurovascular bundle of the upper limb must traverse the narrow cervico-axillary canal to enter the axilla. In addition, the vessels must pass over the first rib from their intrathoracic origin. In thoracic outlet syndrome (TOS), the wide range of movement of the shoulder joint changes the shape and size of this channel, and a range of arterial (aTOS 1–2%), venous (vTOS 3–5%) and neurological (nTOS 95–99%) symptoms are reported that may be due to impingement of these structures.[14] Most patients can be managed conservatively with reassurance, lifestyle changes and physiotherapy. A minority may benefit from surgical intervention:

- *Neurological symptoms* of pain, paraesthesia and paresis are caused by pressure on the cords of the brachial plexus. The pressure is more often from the scalene muscles, which are attached to the first rib, rather than from the rib itself. Aberrant scalene bands to a rudimentary cervical rib are also implicated.
- *Vascular symptoms* are much less common than neurological symptoms and account for only 5% of the cases. The fulcrum for the compression is the cervical or first rib (Figure 19.6). Vascular compression may give rather non-specific symptoms, but complications such as a venous thrombosis or an arterial stenosis or aneurysm can occur.

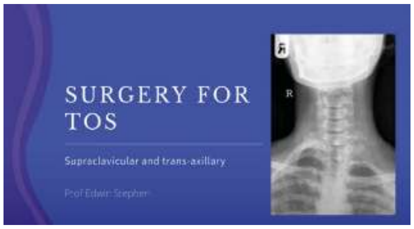
SURGICAL APPROACH

Surgery for TOS is an uncommon operation in vascular surgical practice, and patients should be referred to surgeons with a special interest, for both assessment and surgery. The surgical objective is the enlargement of the space for the neurovascular bundle. This may involve removal of a cervical rib or fibrous bands or, if the skeletal anatomy is normal, partial first rib excision with release of the scalene muscle attachments (scalenectomy). Operations for TOS can be either trans-axillary or supraclavicular. The choice of approach is dependent on what structure is predominantly implicated in the compression. For example, cervical rib excision and the more extensive scalenectomy advised for upper brachial plexus compression require a supraclavicular incision. Lower brachial plexus compression and vascular compression are satisfactorily released by an excision of the middle portion of the first rib and the release of the scalene attachments to the rib. This is generally undertaken from an axillary approach. However, if arterial reconstruction is anticipated, necessitated by a stenosis or aneurysm, a supraclavicular approach will provide superior vascular access.



19.6 Anteroposterior view of the cervical spine and upper thoracic spine showing bilateral cervical rib. ⏎

Details of the surgery of TOS are available in specialist vascular textbooks, but the two standard operations are summarised below and in the following YouTube video:



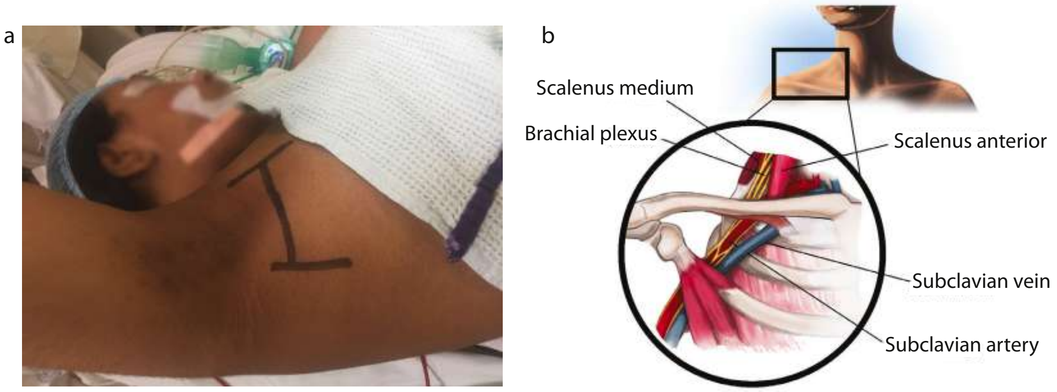
SURGERY FOR TOS

Supraclavicular and trans-axillary

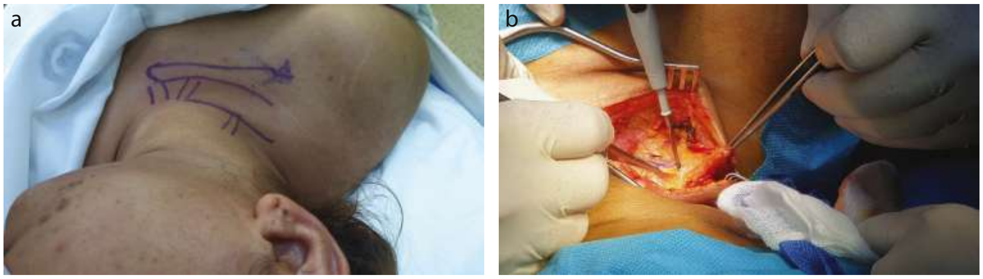
Prof Edwin Stephen

Axillary approach

With an axillary approach, the patient is anaesthetised and stabilised in a semi-lateral position with the arm abducted and supported. It is advisable for the surgeon to use a headlamp for better visibility.



19.7 (a) Incision along the right axillary hair line. (b) The view of the right first rib and the subclavian artery and vein from the axillary approach, with the arm abducted. (We thank Dr Hajar Al Balushi and Ms Ruqaiya Al Balushi for the illustration.) ⏎

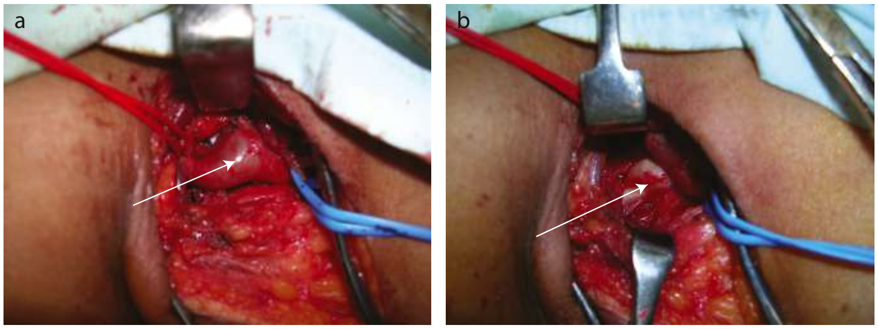


19.8 (a) Preoperative marking of the clavicle, two heads of the sternocleidomastoid muscle and the external jugular vein. (b) Supraclavicular pad of fat mobilised. ⏎

A transverse incision is made in the axilla, just below the axillary hair line (Figure 19.7a). An axillary tunnel is developed up to the first rib on the surface of the serratus anterior. Intercostal brachial nerves will usually have to be sacrificed. The dissection is then over the first rib, taking great care not to damage the subclavian artery, the subclavian vein and the brachial plexus (Figure 19.7b). The vessels are gently separated from the rib and from the scalenus anterior, which is then divided. A diathermy should be used over the first rib, then a flat periosteum elevator should be used to push away the overlying intercostal muscle, dividing the anterior scalene. It is useful to have a thin Deaver retractor, which keeps the pectoralis major and upper margin of the wound out of the away. The distal portion of the muscle should be excised because, if it is simply released, adhesions from the cut end can cause recurrent symptoms. The scalenus medius, and the tendon of subclavius, can also be divided for additional release. The rib is then divided posteriorly behind the T1 and C8 nerves, which must be identified and protected (the assistant pulls the arm up, gently, to keep the plexus away), and finally anteriorly near the costochondral junction, while the subclavian vein is gently held out of the way.

Supraclavicular approach

The patient is positioned supine, shoulder rolled, neck extended and head rotated to the opposite side, with both hands tucked in on the side. With this approach, an incision one finger breadth above the medial half of the clavicle is deepened through the platysma (Figure 19.8a); the supraclavicular pad of fat is mobilised laterally (Figure 19.8b); the phrenic nerve overlying the scalenus anterior muscle is identified, looped and preserved; and the subclavian artery is exposed after careful division of the fibres of the scalenus anterior muscle from its attachment onto the first rib (Figure 19.9a). The scalenus medius is also excised. A word of caution is that it is easy to stray laterally during the dissection and injure the brachial plexus. The central portion of the first rib can also be excised from a supraclavicular approach, but access is more limited, and this can be technically more challenging compared with the transaxillary approach. When an accessory cervical rib (Figure 19.9b) is present, it is usually surrounded by scalenus medius, with tendinous attachments both to the cervical rib and to the first rib. The accessory rib is cleared of muscular attachments, disarticulated anteriorly and divided posteriorly, level with the transverse process. Great



19.9 (a) Right subclavian artery aneurysm (white arrow) with red vessel loop proximally and blue loop distally. (b) Cervical rib (white arrow) below the aneurysm. ⏎

care is necessary to avoid damage to the T1 nerve root during this manoeuvre.

CAROTID ARTERY SURGERY

CAROTID ARTERY STENOSIS

An area of vascular surgery that has been examined extensively by randomised controlled trials is the management of carotid artery stenosis. Since the late 1980s, a series of trials have provided vascular surgeons with help and guidance about patient selection for carotid endarterectomy (CEA) or carotid artery stenting. In summary, intervention is indicated for symptomatic carotid territory embolic disease if the degree of stenosis is moderate to severe but the vessel remains patent. The benefits are time dependent. The risk of a further embolic event is greatest immediately after the initial symptoms, but diminishes rapidly. Patients with asymptomatic lesions may also derive limited benefit from intervention. Quality control is paramount and there is significant heterogenicity throughout the published literature. A vascular surgeon must always remember that both arms of the major trials have included best medical therapy in the form of antiplatelet therapy, lipid profile therapy, good glycaemic control and optimal blood pressure control and that best medical therapy itself has continued to evolve since the trials.[15]

Controversies surrounding CEA include the use of shunts and patches and the type of anaesthesia administered. More recently, it has become clear that carotid artery stenting is both feasible and relatively safe. Debate and deliberations are now focused on which procedure, CEA or carotid artery stenting, is safest and most durable.[15] The authors recommend a multidisciplinary team meeting (with a neurologist, radiologist, endovascular surgeon and interventional radiologist) prior to intervention.

Anaesthesia

CEA can be performed under regional anaesthesia, using both superficial infiltration and a deep cervical plexus block. This has the advantage of allowing selective shunting of patients based on deteriorating neurological status following the application of a vascular clamp. The patient’s motor and sensory functions can be assessed objectively, and the higher functions can be gauged by simple conversation. Despite these theoretical advantages, a recent trial has shown no difference in outcome. The decision over whether general or regional anaesthesia is used should therefore depend on the preferences of the patient, surgeon and anaesthetist.[15]

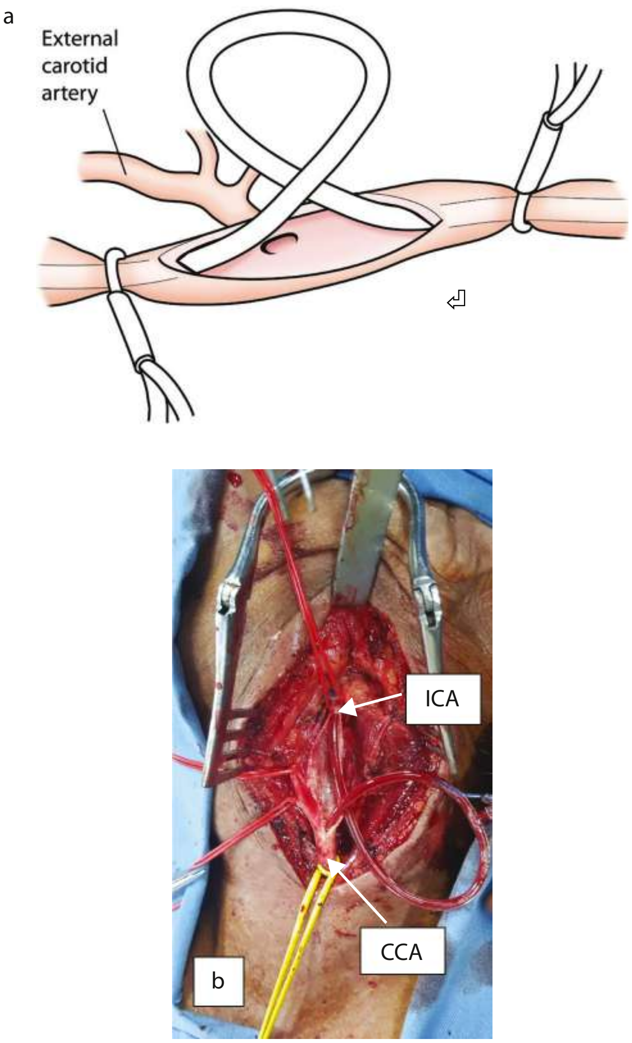
Shunts

Shunts between the common carotid artery (CCA) and the internal carotid artery (ICA) during CEA may be routine or used on a selective basis (Figure 19.10). Methods of estimating cerebral perfusion include transcranial Doppler and ICA stump pressures. However, none has given a completely reliable measure of adequate oxygenation. Although a shunt should improve cerebral perfusion during this period, shunt insertion itself carries a risk of vessel dissection, rupture and pseudoaneurysm formation, and, even with a shunt in place, there is an argument that estimations of cerebral perfusion are still necessary to ensure that the shunt is working.

Patches

The materials used to patch a carotid artery depend on availability and surgeon preference. The materials include vein (the authors prefer using the GSV above the ankle, as it is thick walled, less prone to aneurysmal change and more resilient to infection), polytetrafluoroethylene (PTFE), polyester, bovine pericardium and polyurethane patch.

There are no randomised controlled trials that compare routine with selective patching, nor any



19.10 (a) A shunt as used in a CEA. (We thank Dr Srujal Shah, vascular surgeon, Ahmedabad, Gujarat, India.) (b) Showing a Pruitt F3® carotid shunt. ⏎

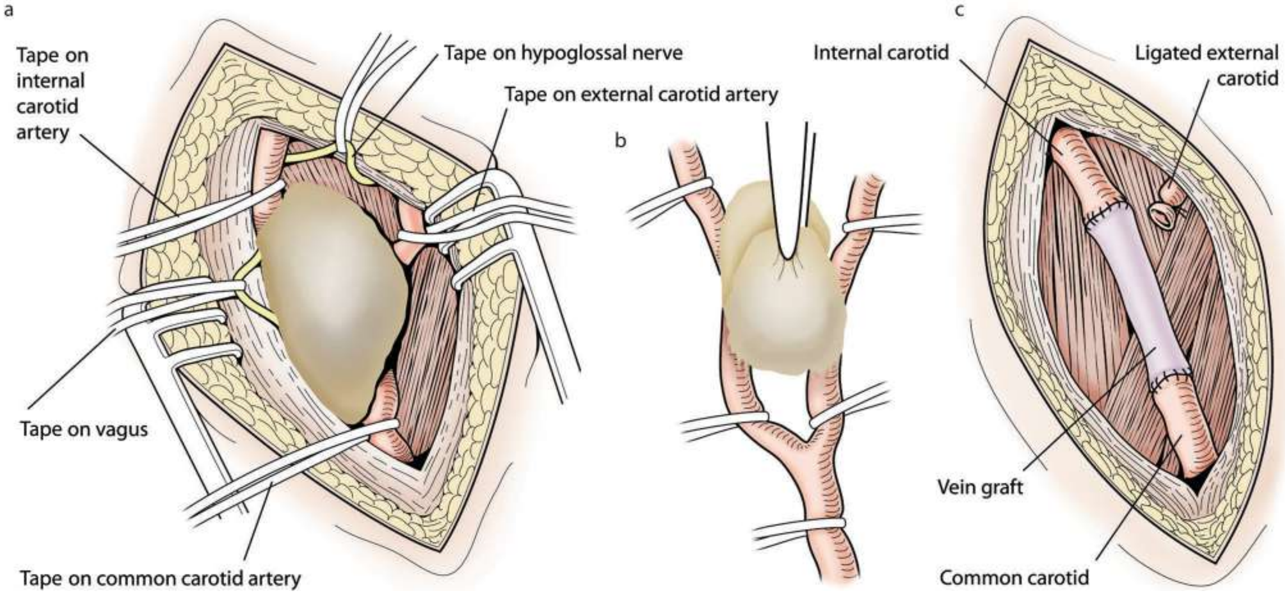
evaluating patching techniques. The European Society of Vascular Surgery and the Society of Vascular Surgery (USA) recommend patching over primary closure, and leave the decision between eversion CEA and patched CEA, as well as the material used to patch, to the discretion of the operating surgeon.[15]

Operative procedure The patient is positioned supine, shoulder rolled, neck extended and head rotated to the opposite side, with both hands tucked in on the side. Exposure of the carotid vessels can be obtained by an incision along the anterior border of the sternocleidomastoid. To avoid damage to the cervical branch of the facial nerve, the upper end of the incision should not approach nearer than 1.5 cm to the angle of the mandible. The platysma and deep fascia are divided in line with the skin incision. The sternocleidomastoid muscle is retracted laterally to reveal the internal jugular vein. This is mobilised, and the common facial vein (under which CCA bifurcation normally lies) and other tributaries to the facial vein are divided. The CCA is exposed first. Note the vulnerable position of the vagus nerve shown on the illustration for carotid body tumours (Figure 19.11). Not only is the vagus itself in jeopardy during dissection, but so is its recurrent laryngeal branch. This is the cranial nerve most frequently damaged during surgery. The external carotid artery (ECA) is exposed and controlled, followed by the superior thyroid artery. The ICA can then be exposed and controlled with a tape. The hypoglossal nerve can then be mobilised and, by dividing the occipital branch of the ECA, the nerve can be pushed up out of the way. The CCA and ICA require adequate exposure for shunt insertion, if necessary. It is also important to expose the ICA to a sufficiently distal level to enable a clamp to be placed above the disease. The upper limit of the disease is often visible from outside the artery as a bluish hue of the vessel. The patient should now receive 3,000–5,000 IU of unfractionated heparin before the clamps are applied: the ICA first and then the CCA and ECA.

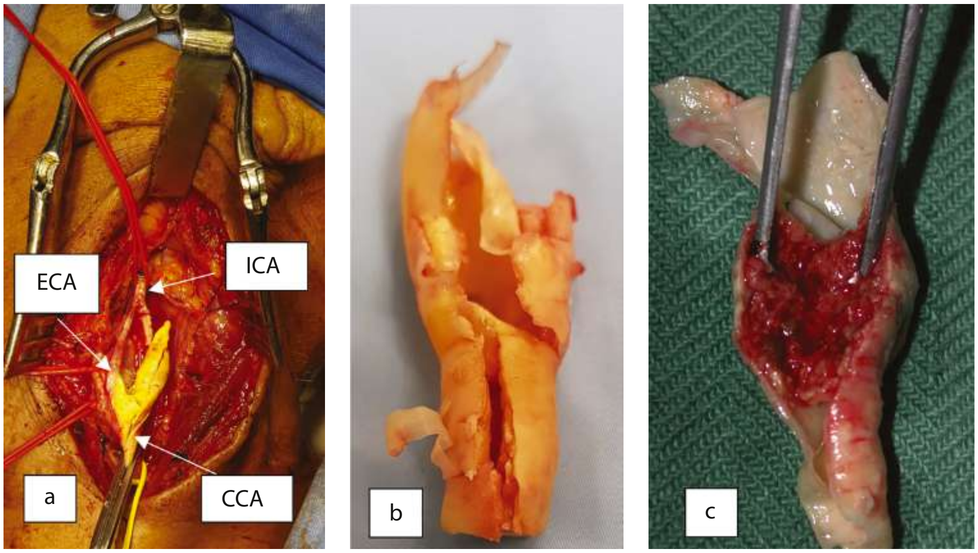
The CCA is opened with a longitudinal arteriotomy, which is extended up into the ICA and should extend both proximal and distal to the atheromatous plaque (Figure 19.12). If a shunt is to be used, it is inserted at this stage. The endarterectomy plane is then entered. This is easiest to identify at the proximal end of the arteriotomy, and gentle outwards traction on the artery wall using forceps can be helpful in providing the initial separation in the correct plane. The dissection in this plane is continued up into the ICA. The plaque normally thins distally and can be followed to its end, avoiding an intimal step in the ICA at the limit of the dissection (see Figure 19.10). If, however, an intimal step is unavoidable, it should be secured with tacking sutures to prevent dissection. Closure is either with, or without, a patch, as discussed above, using 7/0 or 6/0 Prolene for the tacking and the latter for the anastomosis or patch.

CAROTID BODY TUMOUR (PARAGANGLIOMA AND CHEMODECTOMA)

The carotid body usually lies on the posterior aspect of the bifurcation of the CCA. A chemodectoma of the carotid body is therefore closely applied to the carotid bifurcation. Although frank malignancy and metastases are uncommon, the histological appearance does not predict either local invasion or metastatic potential. As the tumour can become progressively more difficult to separate from the carotid arteries as it enlarges, early excision is usually recommended.


a
Tape on internal carotid artery
Tape on hypoglossal nerve
Tape on external carotid artery
Tape on vagus
Tape on common carotid artery
b
c
Internal carotid
Ligated external carotid
Vein graft
Common carotid

19.11 Carotid body tumour. (a) Tapes have been placed around the CCA, ICA and ECA and around the vagus and hypoglossal nerves. (b) The tumour is dissected off the vessels in the subadventitial plane. (c) When the arteries have to be excised with the tumour, the ECA is ligated but a graft is interposed between the CCA and ICA. ⏎


ECA
ICA
a
CCA
b
c

19.12 (a) The atheromatous plaque being mobilised. (b, c) Atheromatous plaque. (For parts (a) and (b), we thank Dr Srujal Shah, Vascular Surgeon, Ahmedabad, Gujarat, India.) ⏎

Clinical diagnosis depends first on clinical suspicion, and many are thought initially to represent a malignant lymph node, as they are very firm on palpation. Further investigations include computed tomography (CT), magnetic resonance imaging (MRI) and angiography.

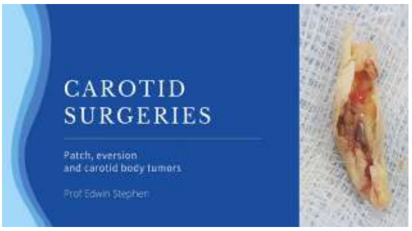
Operative procedure

The approach to the carotid bifurcation is similar to that for a CEA and has been described above. Proximal control of the CCA is the first step and, if possible, further tapes are placed around the distal ICA and ECA. Dissection at the outer boundaries of the tumour allows the isolation, ligation and division of large thin-walled tumour vessels, and increased mobility of the tumour is achieved. Rotating the tumour forwards, top down, allows the vagus to be identified and separated from the tumour. The tumour is then also held in a tape (see Figure 19.11a).

The tumour is dissected off the carotid arteries. In most cases, there is a subadventitial plane of cleavage that can be followed (see Figure 19.11b). The tumour blood supply is often predominantly from the ECA.

The use of a Harmonic® scalpel (if available) is a safe and efficient way to proceed down the plane between the ECA and the tumour. The arterial wall is left otherwise intact, and aneurysmal dilation is not a complication. When the tumour is circumferential, it may have to be transected until the correct plane is reached. However, in some tumours, this subadventitial plane cannot be followed and a segment of the carotid arteries must be resected with the tumour. A carotid reconstruction is then performed with a vein graft anastomosed to the CCA below the tumour and to the ICA above it. The ECA is simply ligated and divided (see Figure 19.11c). During the resection and reconstruction, a temporary shunt is usually established to maintain inflow into the ICA and to safeguard cerebral perfusion.

The YouTube video listed below covers the topics of carotid endarterectomy and carotid body tumours.



CAROTID SURGERIES

Patch, eversion and carotid body tumors

Prof Edwin Stephen

ARTERIOVENOUS FISTULA CREATION

Patients who require an AVF are referred by nephrologists either before the need arises (pre-emptive) or once haemodialysis has been started. These patients are to be assessed for suitability by clinical examination and an ultrasound to assess vein and artery size. Increasing age, diabetes mellitus, female gender, obesity, PAD, thrombophilia and surgeon experience are some of the factors that determine patency of an AVF.[16] The principles followed include:

- Undertake a peripheral pulse examination and Allen's test to check for ulnar patency.
- Create an AVF in the non-dominant hand.
- Preferably start at radiocephalic fistula, then move to brachiocephalic fistula, then to single/two-stage brachiobasilic fistula/brachiobasilic vein transposition. Arteriovenous graft as a loop or straight graft is reserved for patients who do not have a suitable vein. Arterio-arterial grafts are best left to trained vascular surgeons.
- For a radiocephalic fistula, a vein and artery diameter between 2 and 2.5 mm is suitable.
- For a brachiocephalic fistula, brachiobasilic fistula or brachiobasilic vein transposition, it is recommended that the vein and artery diameter be at least 3 mm.
- Veins are best assessed after applying a tourniquet proximally.
- The risk of 'vascular steal syndrome' is higher if the arteriotomy is more than 1.5 times the diameter of the artery and/or if the patient has PAD. The patient should be advised about 'hand precautions' before and after surgery. This mainly includes not taking blood samples from potential veins, avoiding blood pressure measurement in the arm after AVF creation, and avoiding flexing the elbow joint to 90° and kinking the new AVF at the elbow.
- In patients who have had previous tunnelled catheters for haemodialysis, a venogram is recommended to ensure there is no central stenosis that can affect maturation of the AVF and patency.

The 'rule of six' for AVF creation should be kept in mind:

- Flow volume >600 mL/min
- Vein diameter >6 mm
- Vein depth <6 mm
- Cannulate-able length of vein of 15 cm (6 inches)
- 6 weeks to maturation/use of AVF
- Needling preferably 6 cm away from the anastomosis
- Needles to be 6 cm apart to prevent 're-circulation' and inadequate haemodialysis

Flow volume and vein depth seem adequate to predict AVF maturation, and reliability of the six rules need not be as stringent.[17]

PROCEDURE

Local anaesthesia is adequate for 'snuff-box', radiocephalic, brachiocephalic and two-stage brachiobasilic fistulas, and regional anaesthesia is adequate for brachiobasilic vein transposition and arteriovenous graft, although patient factors need to be considered while choosing the best option. It is advisable to have a 'hand table' to support the arm while performing the procedure.

Mark the vein preoperatively and, if needed, the artery too. Be careful not to injure the vessels in patients with low body fat while dissecting. The anastomosis can be either end-to-side, which is the authors' preference, or side-to-side and performed using 6/0 or 7/0 Prolene sutures.

The YouTube videos listed below show the following topics:

- Preoperative ultrasound, https://youtu.be/RQh4AUycj-M

- Dissection of the cephalic vein and the exposing brachial artery, https://youtu.be/ILs44PySkZY

- Mobilisation of the basilic vein, https://youtube.com/shorts/HIOyQl7lThs

- Closure after superficialising of the basilic vein, https://www.youtube.com/watch?v=MQyZhfPwaes

RISKS AND COMPLICATIONS

Risks and complications include bleeding, haematoma, infection, aneurysmal changes in the vein, pseudoaneurysm formation, steal syndrome, venous hypertension, oedema and dilated veins (Figure 19.13).

DIABETIC FOOT

The diabetic foot is always at risk of a 'diabetic foot attack', especially when the patient presents with an inflamed foot, which can rapidly progress to tissue loss, sepsis and amputation without appropriate intervention. It should be remembered that 'time is tissue', especially in feet that are infected and/or ischaemic.[18]

The 'rule of 15' applies in patients with diabetes:

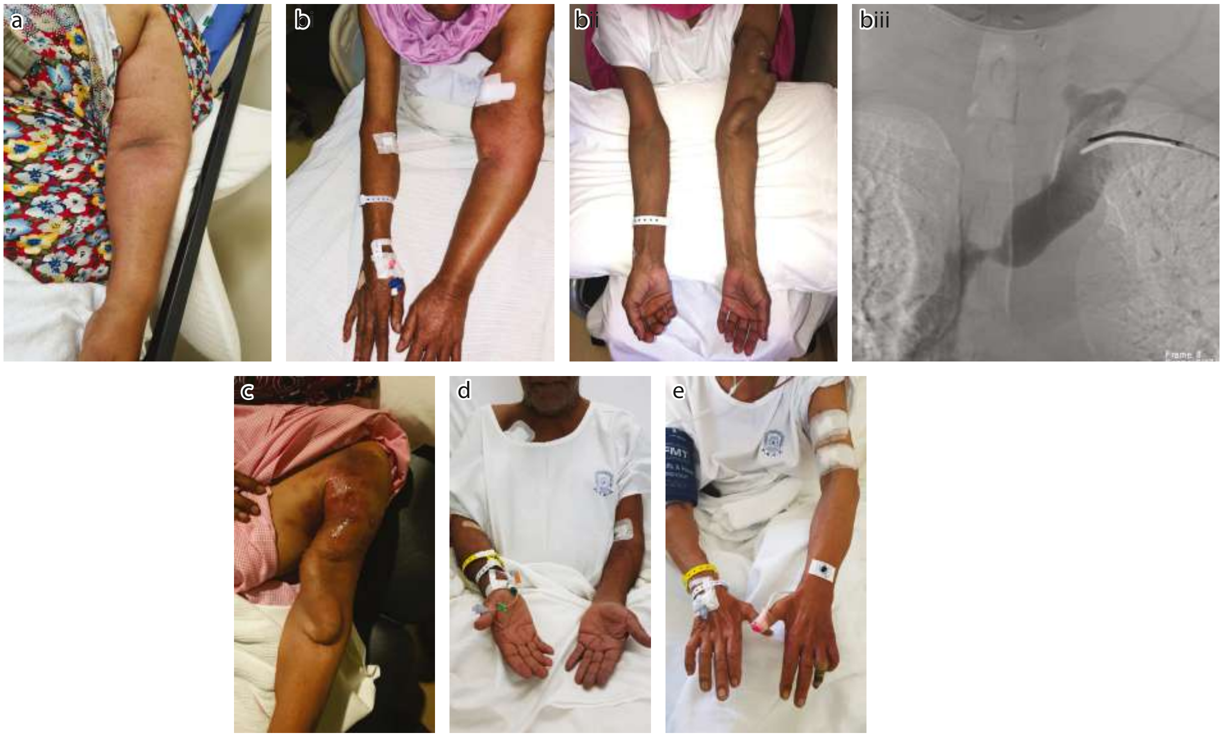
- 15% of patients with diabetes develop foot ulcers
- 15% of ulcers develop osteomyelitis
- 15% of ulcers result in amputation
- 85% of amputations have a history of diabetic foot ulcer
- 85% of amputations are preventable (Figure 19.14)[19]

Figure 19.15 shows a recommended algorithm for appropriate referral to a vascular and endovascular surgeon.

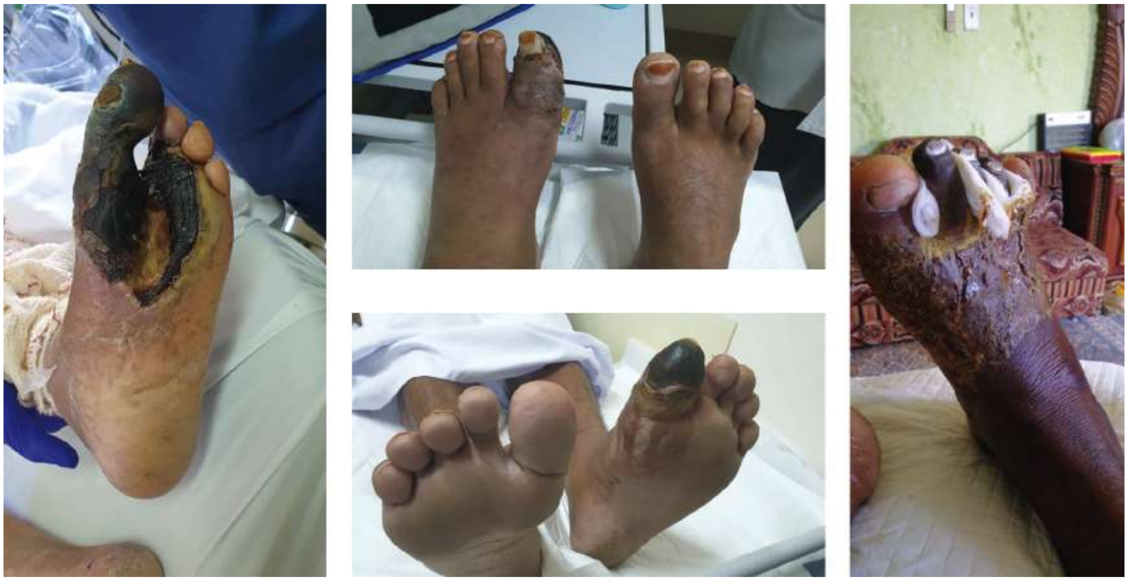
VASCULAR MALFORMATIONS

Vascular malformations are abnormal vessels that involve the venous, lymphatic, capillary and arterial systems individually or more often in combination. Malformations can occur from head to toe (Figure 19.16). Venous malformations are the most common, followed by veno-lymphatic malformation; intramuscular slow flow malformation; complex malformation – Klippel–Trenaunay syndrome; CLOVES (congenital lipomatous overgrowth, vascular malformations, epidermal nevi and spinal/skeletal anomalies) syndrome; and arteriovenous malformation (AVM).[5] The reader must bear in mind that usually there is more than one malformation and more than one region may be involved; hence, a through physical examination is mandatory.

Managing a vascular malformation requires the surgeon to be aware of various modalities that can be used to treat them, which include sclerotherapy, embolisation, excision and the use of medications such as propranolol and/or sirolimus.[20] A multidisciplinary meeting is recommended between general/vascular/plastic surgeons, an interventional radiologist, a radiation specialist, a haematologist, a blood bank team, an orthotist and a physiotherapist.



19.13 (a) Postoperative brachiocephalic AVF with cellulitis and venous hypertension causing oedema. (bi–iii) Venous hypertension with central stenosis. (c) Aneurysmal dilatation of cephalic vein. (d) Early steal syndrome. (e) Delayed presentation of steal syndrome. ⏎

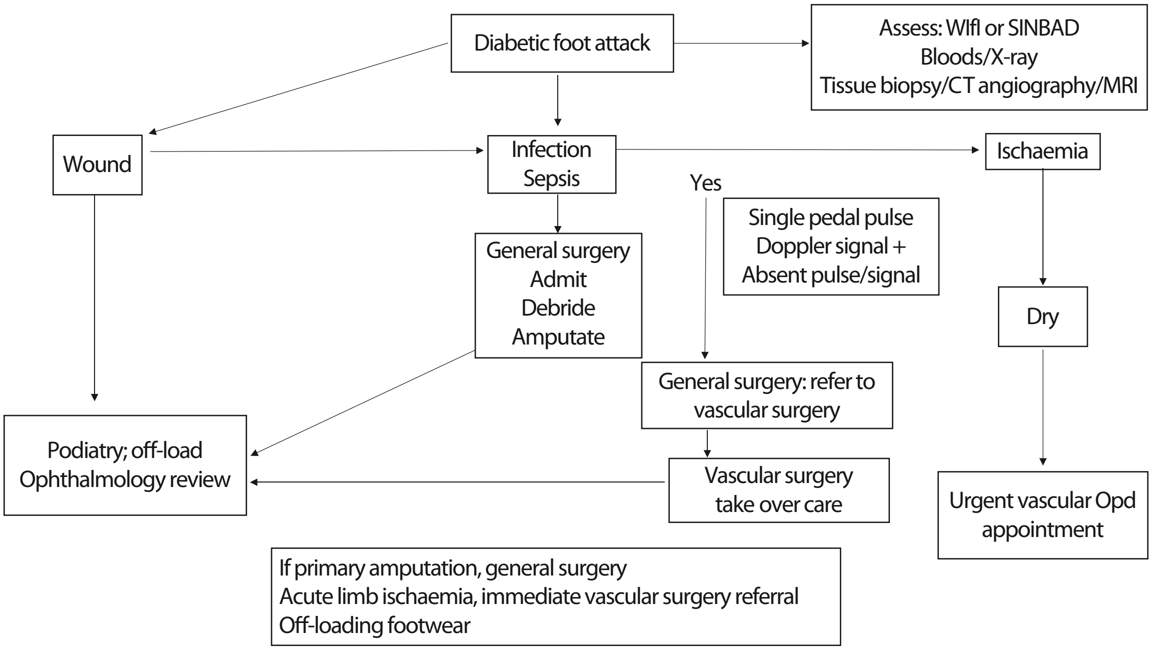


19.14 Examples of presentations of diabetic foot. ⏎

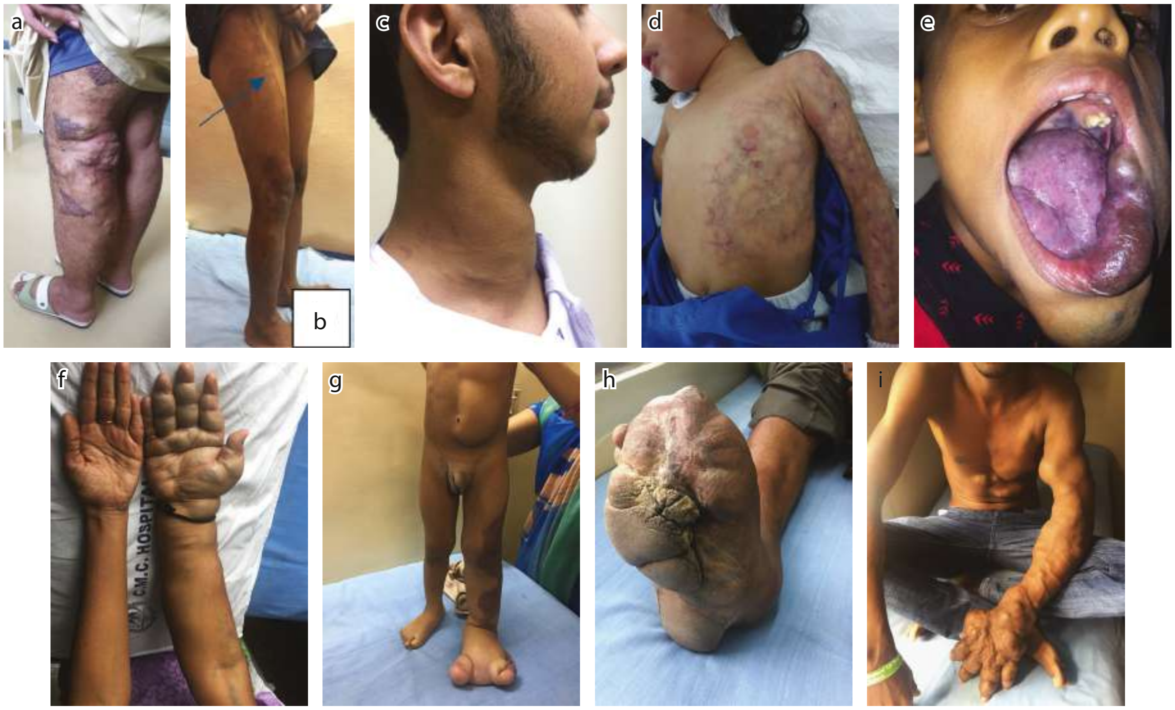
It is best to manage vascular malformations symptomatically until children have become adults. Custom-made compression garments are a mainstay in treatment.

Small venous malformations can be excised, provided skin closure is possible. If the overlying skin is not involved, then sclerotherapy can help reduce the size of the venous malformation, enabling closure or a smaller area to be skin grafted.

AVMs are best left to be managed by experts in the field in view of the complexity of the pathology. Large AVMs can lead to cardiac failure in some patients.


Diabetic foot attack
Assess: WIfI or SINBAD
Bloods/X-ray
Tissue biopsy/CT angiography/MRI
Wound
Infection
Sepsis
Ischaemia
Yes
Single pedal pulse
Doppler signal +
Absent pulse/signal
General surgery
Admit
Debride
Amputate
Dry
General surgery: refer to vascular surgery
Podiatry; off-load
Ophthalmology review
Vascular surgery take over care
Urgent vascular Opd appointment
If primary amputation, general surgery
Acute limb ischaemia, immediate vascular surgery referral
Off-loading footwear

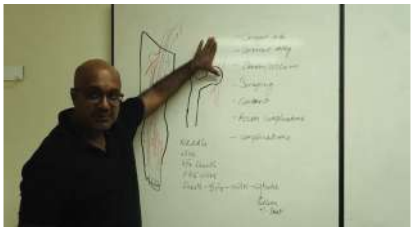
19.15 Suggested algorithm for management of diabetic foot and referral to a vascular surgeon. Opd – Out-patient department; SINBAD – Site, Ischaemia, Neuropathy, Bacterial infection, Area and Depth; WiFi – Wound, Infection, Ischaemia. ⏎



19.16 (a, b) Klippel–Trenaunay syndrome; the blue arrow shows the lateral marginal vein. (c) Neck AVM. (d) Veno-lymphatic malformation. (e) Venous malformation: lip and cheek. (f) Venous malformation: right forearm/hand. (g) CLOVES syndrome. (h) Foot AVM. (i) Venous malformation: arm, forearm, hand and chest wall. ⏎

ENDOVASCULAR BASICS

The following YouTube video outlines the basics of the topic:



INFRARENAL AORTIC ANEURYSMS

The first successful resection of abdominal aortic aneurysm (AAA) with graft replacement was performed on 29 March 1951, by Charles Dubost in Paris.[21] He used an extraperitoneal thoracoabdominal approach with resection of the 11th rib. The graft used was the thoracic aorta taken 3 weeks previously from a 20-year-old woman. Aneurysm repair continues to evolve, with new innovations extending the boundaries of endovascular repair. Aneurysmal dilatation may be localised to the aorta or extend into the iliac arteries. Fortunately, aneurysmal dilatation involving the suprarenal or thoracic aorta is less common, as the surgery for these thoracoabdominal aneurysms is technically challenging, with significantly higher rates of adverse events. AAAs are predominantly secondary to atherosclerotic degeneration, a process that may also result in occlusive disease. Genetic and family history also plays a role in the aetiopathogenesis of aneurysms.

SELECTION

Elective repair of infrarenal AAAs is a prophylactic procedure to prevent death by rupture. Open repair is associated with a mortality rate of around 3% in high-volume centres. Endovascular aneurysm repair (EVAR) has a 30-day mortality of less than 2%. After rupture, the mortality rate in the minority who survive the initial bleed, subsequently reach hospital and are selected for repair may be as high as 50%. It therefore seems appropriate to identify those at risk of rupture and to offer surgery before rupture occurs. However, the true natural history of aneurysms remains undefined. Evidence from the UK Small Aneurysm Trial suggested that the rupture rate of AAAs of less than 6 cm in anteroposterior diameter on ultrasound scan had previously been overestimated and that surveillance of these small aneurysms was appropriate.[22] It is now generally accepted that intervention should be considered when the anteroposterior diameter exceeds 5.5 cm in men and 5 cm in women.[23]

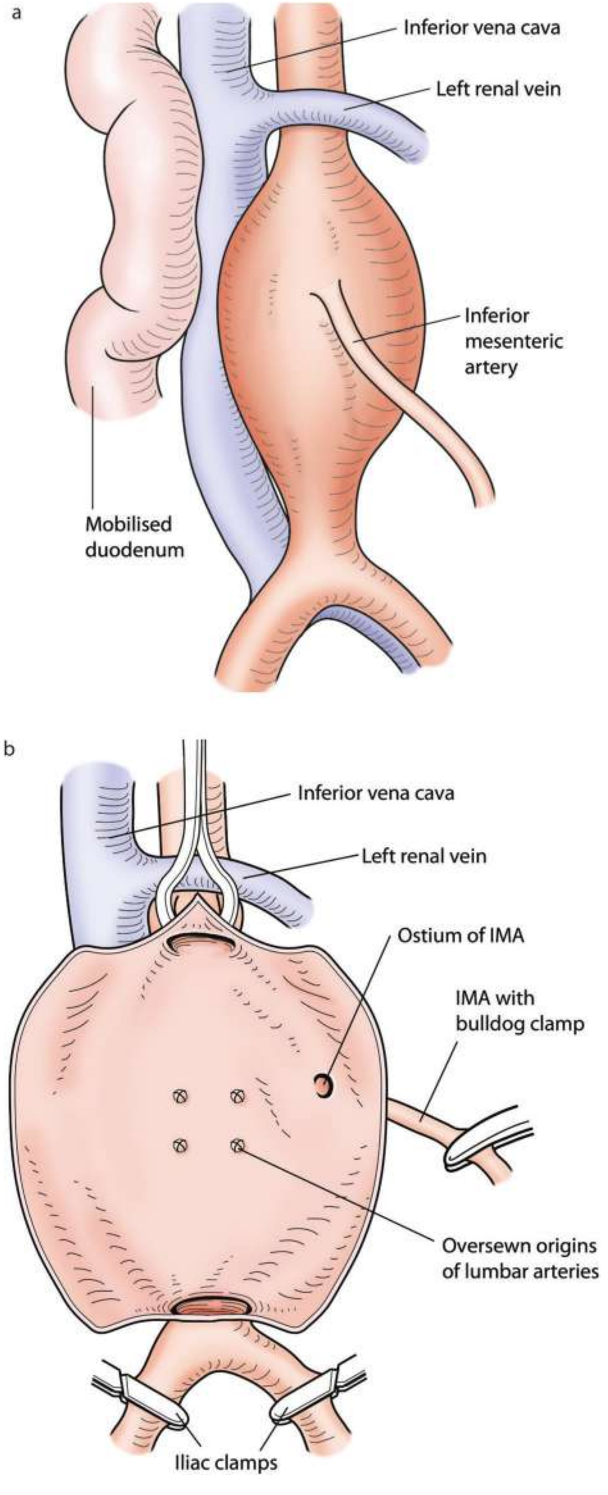
Patient selection and preoperative investigations are based on well-determined guidelines that are now available.[23,24] Patients considered for elective AAA repair require assessment over and above simple exercise tolerance estimation and electrocardiography. Echocardiography (with or without pharmacological stress), an assessment of renal and pulmonary function (spirometry) and cardiopulmonary exercise testing are advocated, but predictive preoperative investigation is far from a precise science and much remains to be refined.

Although simple ultrasound is useful to diagnose and monitor AAA growth, more detailed anatomical information is required preoperatively to exclude suprarenal aneurysmal extension; to verify the position and number of renal arteries, the presence of retroaortic/circumaortic renal vein, graft size, calcification and graft configuration (straight/Y-graft); and to identify iliac artery aneurysmal or occlusive disease. CT angiography is currently the standard investigation for operative planning.

THE OPERATION

The patient is usually operated on in a supine position; in addition, skin preparation and draping must allow access to the femoral vessels if an embolectomy or bypass is required. Prophylactic antibiotics are administered according to protocol for a clean operation. The abdomen may be opened using a midline or a supraumbilical transverse incision. A midline longitudinal incision provides better access to the pelvis, while transverse incisions might provide the advantage of better postoperative respiratory function and lower incidence of incisional hernias. The transverse colon is lifted up and packed superiorly and the small bowel is displaced to the right into a bowel bag outside the abdomen or packed within the abdomen. An incision is made just lateral to the fourth part of the duodenum, leaving sufficient peritoneum as a cuff to allow restoration of peritoneal coverage afterwards. The third part of the duodenum is mobilised from the front of the aorta, and the pre-aortic tissue is divided to approach the neck of the aneurysm on the bare anterior aortic wall. The inferior mesenteric vein is routinely encountered, ascending on the left of the aorta, and is either divided between ties or displaced upwards and lateral.

The dissection is routinely continued up to the level of the left renal vein (LRV), not only to create sufficient room to clamp above the aneurysmal tissue, but also to confirm the anatomy with a landmark visible on CT (Figure 19.17). Occasionally, it is necessary to divide the LRV, close to the inferior vena cava (IVC),

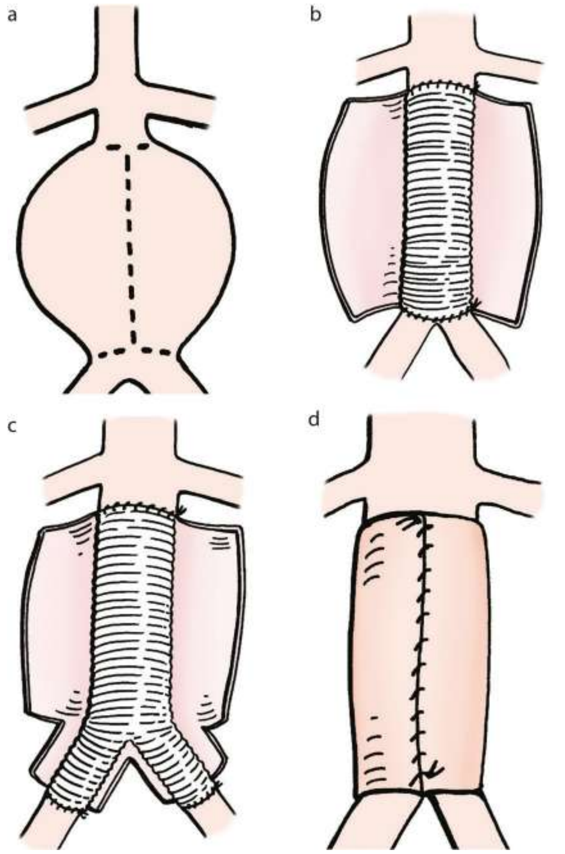


19.17 Abdominal aortic aneurysm repair. (a) Exposure of the neck of the aneurysm. (b) The opened aneurysmal sac. Note the open ostium of the inferior mesenteric artery (IMA), which will be excluded by the graft. ⏎

for better exposure. The gonadal veins and suprarenal veins provide adequate collateral circulation, and the division of the LRV is not associated with long-term decrease in renal function.[25] Aortic aneurysms rotate and lengthen as well as expand in diameter, and the sides of the aorta need to be exposed carefully to avoid damage to lumbar arteries, as well as to an accessory renal artery. Tearing the left iliolumbar or gonadal veins is a significant hazard, and sometimes it is easier to divide these vessels between clips, rather than attempt to preserve them. Exposure of normal aorta just proximal to the aneurysm – often referred to as the neck – is not complete until a clamp slides easily down the sides and rests on the spine.

The next objective is to expose and control the iliac arteries, with awareness of the course of the ureter. It is not necessary, or desirable, to pass tapes or slings around the common iliac artery. This is potentially hazardous, risking damage to the often adherent iliac veins. The right common iliac artery is covered only by a single layer of peritoneum and retroperitoneal fat. The first part of the left common iliac artery is immediately deep to the peritoneum, and this may allow adequate access for clamping depending on the distal extent of the aneurysm or any occlusive disease. Frequently, the aneurysmal process on one or the other side extends up to the iliac bifurcation. It may be necessary to clamp the external iliac artery, requiring partial mobilisation of the sigmoid colon and clamp placement just above the inguinal ligament. The internal iliac artery (IIA) must be exposed to allow separate occlusion. The perfusion of the pelvic organs requires some thought, as, after sacrificing the inferior mesenteric artery (IMA), the rectum is dependent on retrograde perfusion from the IIA. Overt rectal or left colon ischaemia requiring surgical intervention occurs infrequently (in 1–2% of cases) following AAA repair, but subclinical mucosal ischaemia may be more common. It is generally considered sufficient to leave a minimum of one of the three arteries (the IMA and the two IIAs) in circulation and, in AAA surgery, the inferior mesenteric inflow from the aorta is lost unless the vessel is reimplanted. If there is brisk bleeding from the origin of the IMA, this usually indicates adequate collateral circulation from the superior mesenteric artery (SMA), and the IMA may be oversewn. If there is luminal compromise of the SMA or the IIA, the back-bleed from the IMA is sluggish. In these situations, it might be better to reimplant the IMA onto the graft. Sometimes, the distal limb of a bifurcated graft can be fashioned to include the origin of the IIA, but occasionally a vessel must be formally reimplanted or a jump graft performed. Decisions regarding bowel perfusion are based on inspection at the end of the procedure.

After adequate exposure of the aneurysm, 5,000 IU of unfractionated heparin is administered intravenously and the vessels clamped. Clamping distally first in elective repair may minimise the risk of embolisation and is certainly recommended if the patient presented with distal emboli. However, in patients



19.18 Diagrammatic representation of an aortic graft. (a) The arteriotomy incisions. (b) An opened sac with an inlay tube graft in position. (c) An opened sac with an inlay Y-graft in position. (d) The sac has been closed over the graft. ⏎

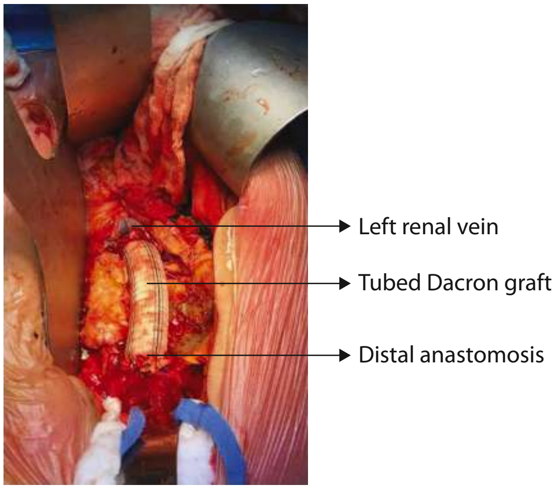
presenting with a ruptured aneurysm, it is prudent to clamp the neck of the aneurysm first to arrest bleeding.

The aorta is opened longitudinally at a convenient site, and care is taken to incise to the right of the IMA origin (Figure 19.18). The arteriotomy is extended up and down the vessel to a distance 2 cm short of the neck proximally and 2 cm short of the bifurcation distally. The distal arteriotomy is usually placed towards the right of the aorta to avoid the hypogastric plexus of nerves that contribute to erectile function. The vessel is retracted open with a self-retaining retractor or sutures. The inside of the vessel is then inspected and the anatomy of the neck and bifurcation confirmed. The thrombus, which is almost invariably present, must be scooped out and the aneurysm sac wiped clean with a swab. Any sites of back-bleeding from the lumbar, inferior mesenteric or median sacral vessels revealed by this must be controlled by a figure-of-eight stitch using 3/0 or 4/0 non-absorbable monofilament sutures. For the IMA, a bulldog clamp, applied plush with the edge of the sac, is more appropriate if reimplantation of the artery is desirable. Often, the back wall of the aorta, particularly at the distal end, is very calcified and a controlled local endarterectomy may be needed to allow a stubborn calcified vessel to be adequately sutured.

The longitudinal arteriotomy incision is then extended to the proximal limit of the aneurysm and converted into a T-shape by cutting at 90° to the longitudinal line of the aorta around the anterior two-thirds of the true circumference of the vessel (Figure 19.18a). At this level, even normal aortic tissue may arch anteriorly and, particularly in the presence of a large aneurysm, care must be taken not to cut straight backwards, as this can make the proximal anastomosis more difficult. The distal end of the arteriotomy is completed in a similar fashion after a decision has been reached as to whether a 'tube graft' or bifurcated 'Y-graft' is more appropriate. If the aorta is of normal calibre for a portion below the aneurysm, or if the common iliac arteries are truly normal and closely opposed, a tube graft may be used (Figure 19.18b). Otherwise, a bifurcated graft is needed (Figure 19.18c). The diameter of the graft to be used can be estimated by sizing the anteroposterior diameter on preoperative imaging or the use of sterile 'sizers' or simply by 'eyeballing' the neck and comparing this with the size drawn on the unopened graft box.

Proximally, an inlay anastomosis is performed (see Figure 19.18b). If bifurcated, the body of the graft must be trimmed to within 3 cm of the diverging limbs in order to avoid kinking. There are a variety of techniques used for the proximal anastomosis. Most frequently, the anastomosis is performed with a continuous 2/0 or 3/0 monofilament, non-absorbable, double-ended suture. The needle is passed from inside to outside the aorta but can be done with suture from outside to inside the aorta under vision if this is easier, as is often the case with smaller aneurysms.

The anastomosis is commenced posteriorly with a mattress suture into the graft and continued in both directions around the posterior and lateral aspects of the anastomosis. After six or so sutures have been placed, they are tightened and the graft is parachuted into position. The anterolateral aspects of the anastomosis are then completed on either side before tying the sutures together just off the anterior midline. An anterior knot immediately over the convexity of the aorta is more likely to come into direct contact with bowel, increasing the likelihood of infective or fistulous complications. Interrupted, evenly spaced mattress sutures or pledgeted (little patches of the graft material) sutures may be an alternative when the aortic wall is grossly thickened and friable. Whatever the chosen technique, the posterior wall must be secured with deep bites, often into and including the anterior spinous ligament. When the proximal anastomosis has



19.19 An infrarenal AAA repaired with a Dacron graft. The upper limit of dissection is the left renal vein, which is seen above the graft. As the aneurysm involved only the aorta, a tubed graft was used and the repair ended above the iliac bifurcation. ⏎

been completed, the graft is clamped 2–3 cm distal to the anastomosis and the proximal aortic clamp is released to test the anastomosis. Any bleeding points identified need to be dealt with as appropriate, after reclamping the aorta. Suturing without reclamping will result in sutures tearing through the aortic wall, resulting in catastrophic bleeding. Figure-of-eight sutures may be enough, but some bleeding may be due to tears in the aortic wall. Interrupted horizontal mattress sutures supported by pledgets are recommended to repair these and to prevent extension of rents in a friable aortic wall. An entire cuff of Dacron, cut from the graft (felt), can be used over a vulnerable anastomosis to provide additional support (Figure 19.19).

The graft needs to be trimmed to its final length, allowing a modest degree of tension to prevent the prosthesis from bowing forwards or kinking. The distal anastomosis is performed in a similar fashion to the proximal. Before completing the suture line, the graft must be flushed by releasing the clamps and allowing the flow of blood to remove any thrombus that has formed. The iliac vessels also need to be opened to demonstrate back-bleeding. If there is no back-bleeding, ‘pumping’ the thigh by external compression may stimulate blood flow. Failing this, it may be necessary to pass downstream Fogarty embolectomy (No 4) catheters to remove clots.

The anaesthesia team must be alerted prior to the release of distal circulation. When distal circulation is restored, a fall in systemic blood pressure and perfusion is likely. This is due to a sudden reduction in systemic vascular resistance and the return of cold, deoxygenated blood laden with free radicals, activated white cells, carbon dioxide and lactic acid, all of which are cardio-depressant and also cause pulmonary vascular vasoconstriction leading to profound hypotension. The clamps must be released one leg at a time. The patient’s vascular compartment should be adequately filled, and fluids and pressor agents should be on hand to deal with a sudden fall in systemic blood pressure. If the pressure drops precipitously, it can be brought up again by partial or full occlusion of the graft. However, a 10–20 mmHg drop in blood pressure and a rise in end-tidal CO_2 is reassuring. This, together with the return of a palpable femoral pulse, indicates the restoration of blood flow to the lower limb.

Before closing the aortic sac and reconstituting the peritoneum over the graft, the following checks are necessary:

- Is the colon adequately perfused and is the IMA back-bleeding? If so, does the origin of the IMA require suture ligation? If the left colon appears ischaemic and the IMA is patent, implantation of the IMA into the graft may be indicated.
- Have any lumbar arteries started back-bleeding now that the distal circulation has been restored?
- Are both femoral pulses present (if they were palpable preoperatively), and are the feet well perfused?

If all is well, the aneurysm sac is sutured over the graft (see Figure 19.18d) and the peritoneum is also restored. The small bowel and omentum can be eased towards their normal positions, and care must be taken to leave no part of the graft exposed to which adjacent gastrointestinal tract could adhere, with subsequent risk of infection or enteric fistula formation. In thinly built patients, the peritoneum might be inadequate to completely cover the graft. A length of omentum with preserved vascularity can be mobilised and used to cover the graft.

RETROPERITONEAL APPROACH

This is an alternative approach for an elective AAA repair. The patient is positioned supine with a tilt elevating the left side. The chest is in the right decubitus position and the torso is rotated with the pelvis only slight elevated from the bed. The patient needs to be positioned with the midpoint between the lowest part of the ribcage and iliac crest over the table break. A sandbag with table straps is useful for maintaining position. The operating table is then jack-knifed to allow the space between the ribcage and pelvis to open up.

A left oblique muscle-cutting incision is made through the 11th interspace, extending from the posterior axillary line to the abdominal midline approximately 1 cm below the umbilicus. The abdominal wall muscles and the peritoneum are retracted medially to give good access to the retroperitoneal abdominal aorta. The left kidney is left in the posterior retroperitoneum and careful dissection is required, especially around the left renal artery, to avoid injury. This approach may be associated with a reduction in ileus and reduced haemodynamic and respiratory compromise, resulting in quicker postoperative recovery. In addition, intra-abdominal pathology, such as adhesions from previous surgery, can be avoided. Access is superior if visceral reconstruction is also necessary. The main disadvantage of a retroperitoneal approach is the poor access that it affords to the right common iliac vessels.

INFLAMMATORY ABDOMINAL AORTIC ANEURYSMS

Inflammatory AAAs (IAAAs) represent 3–10% of all AAAs and have a predilection to occur in men. It is interesting to note that the age of occurrence is 5–10 years younger than the mean age of patients with atherosclerotic aneurysm.[26] IAAAs are now defined by the presence of a thickened aneurysm wall, marked peri-aneurysmal and retroperitoneal fibrosis, and dense adhesions of adjacent abdominal organs.[27] Certain features support a preoperative diagnosis, for example presentation with a systemic illness, including fever and malaise, and raised inflammatory markers, the appearance of a halo around the aneurysm or an associated hydronephrosis (due to ureteric obstruction) that may have been detected on imaging. Some patients with inflammatory aneurysms present with symptoms relating to ureteric obstruction, and urological investigations lead to the diagnosis.

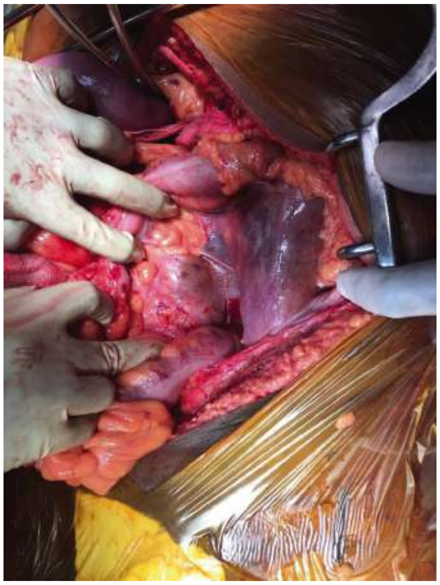
As the surrounding inflammation offers no protection from rupture, the indications for surgery are similar to those for other AAAs, but with increased operative difficulty. At operation, the patient is more likely to require a suprarenal clamp, and the surrounding structures, particularly the duodenum, are at greater risk of damage. It may be necessary to clamp the aorta without separating the duodenum from the aneurysm. The patch of aortic wall adherent to the duodenum can then be excised from the aorta after the aorta has been opened, leaving the adherent patch of aneurysm wall on the duodenum. Ureterolysis is advocated by some, but the risk of ureteric damage is high. It is usually unnecessary, as the inflammation tends to settle following surgery and ureteric obstruction usually resolves. Ureteric obstruction at presentation can be managed by ureteric stents and the placement of stents preoperatively will help reduce the risk of iatrogenic injury, especially when dissecting around the iliac artery.

RUPTURED ABDOMINAL AORTIC ANEURYSM

Preoperative management

The diagnosis may be straightforward. A history of collapse together with a clinical, or ultrasound, finding of an AAA is sufficient grounds upon which to suspect rupture, especially if the patient is unstable. Occasionally, diagnostic difficulties occur regarding either the presence of an aneurysm or whether rupture has occurred. A CT should not be performed in haemodynamically unstable patients, but may be helpful, particularly if an alternative diagnosis is found. However, it cannot be completely relied upon to exclude rupture of an AAA.[28]

The surgical principles for repair of the ruptured AAA differ only a little from the elective situation. However, mortality is much higher. In the UK, most surgeons operate selectively on ruptured AAA (Figure 19.20). Experienced clinical judgement is essential, but these difficult decisions can now be supported by scoring systems.[29,30]



19.20 A ruptured AAA. The bluish discoloration is due to retroperitoneal haematoma. ⏎

After the decision has been made to proceed, there is often considerable urgency. Although an arterial line is helpful, it should not delay induction of anaesthesia; both this and central venous cannulation can wait until surgery is underway and an aortic clamp is in place. Urethral catheterisation and good peripheral venous access are, however, essential, as is communication with the blood transfusion service so that blood can be cross-matched and fresh-frozen plasma and platelets organised. There is often a dramatic fall in blood pressure on induction of anaesthesia, in part due to the loss of tamponade as abdominal muscle tone is eliminated following paralysis. Therefore, the patient should be prepared and draped prior to induction of anaesthesia so that there is no unnecessary delay before the haemorrhage can be controlled surgically.

The operation

The operative procedure is essentially the same as described above for the elective situation. A transverse incision may still be chosen over a midline: access is usually adequate. However, many consider a midline incision to be a quicker approach.

It is rare for a patient to survive to reach the operating theatre with free intraperitoneal rupture. When a free rupture is encountered at laparotomy, pressure applied directly to the neck of the aneurysm may control the bleeding. Alternatively, an aortic balloon catheter (or large Foley catheter) can be passed up the aorta, beyond the neck of the aneurysm (see Figure 18.3a). This is a difficult manoeuvre in an emergency situation and may lead to significant blood loss. If control at the neck is still difficult, then the aorta can be temporarily clamped through the lesser sac. A window is opened in the lesser omentum and the aorta can be exposed and clamped by separating the fibres of the diaphragmatic crura from the aorta. Visceral ischaemia will occur, and the effects of clamp release will be profound. Therefore, the clamp should be moved down to an infrarenal position as soon as this is possible.

Fortunately, the situation is usually a stable one; the haematoma is contained by the peritoneum and a careful dissection can be performed. The duodenum is most frequently displaced to the right by the haematoma and, therefore, is already partially mobilised. Dissection can proceed with division of the peritoneum and exposure of the aneurysmal aortic wall. The aorta should be followed superiorly, dividing the inferior mesenteric vein as it is encountered. Bleeding, either active or from the haematoma, will inevitably obscure the view, and the assistant needs to be active with suction in one hand and a retractor in the other. The surgeon might be required to retract the small bowel to the right of the midline and use the hand to palpate for aortic pulsation, in tandem with blind finger dissection around the lateral aspect of the aortic wall. A long curved aortic clamp can be placed after the spine can be palpated with fingers posteriorly. Careful clamp placement is essential. It is easy to damage the IVC, LRV or any other adjacent vein by hastily forcing a clamp into place. Care must be taken to identify the neck of the aneurysm, and this often requires dissecting all the way up to the renal vein, as in the elective case. Usually, the aorta is clamped before exposing the iliac vessels. If the iliac arteries are also aneurysmal, they must be excluded by the repair. It is also possible that the rupture has occurred through the wall of an iliac artery.

If the situation is truly stable and the haematoma is modest in size, some surgeons will administer heparin once the aorta is clamped; the patient is more likely to suffer a thrombotic complication than a haemorrhagic complication. Other surgeons flush heparinised saline down the iliac systems to reduce the possibility of iliac or femoral thrombosis while the repair is being performed.

Repair proceeds as for elective AAA surgery, but special care must be taken to ensure that the iliac arteries are back-bleeding before completing the distal anastomosis. If there is no back-flow of blood from the legs, it is prudent to sweep the distal vessels with a Fogarty catheter at this stage. As with the elective situation, perfusion of the feet must be checked before the patient is taken from the operating table.

Inevitably there are occasions when the situation is not salvageable:

- The patient may arrest or suffer a myocardial infarction with a loss of cardiac output despite the use of inotropes.
- Irreversible coagulopathy may develop.
- The aneurysm may be inoperable (e.g. extension high above the renal arteries) or the aortic defect may be exposed by dissection, and rapid and uncontrollable haemorrhage may ensue.
- A decision to abandon the procedure may have to be made. This is best taken in conjunction with other colleagues present.

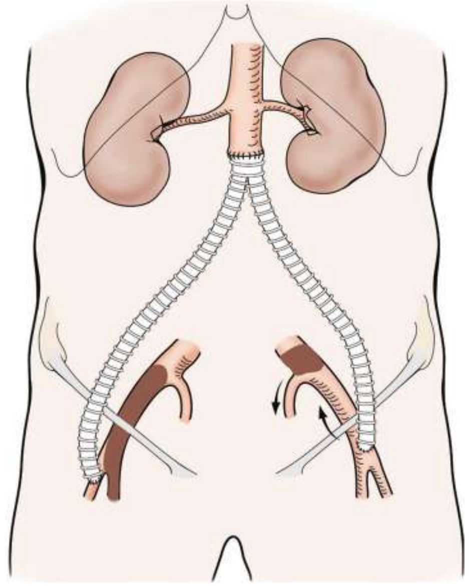
Aortocaval fistula

Occasionally, an aortocaval fistula is encountered. This may have been suspected preoperatively if the patient presented with high-output cardiac failure and was noted to have mottling of the lower half of the body despite apparently adequate perfusion in the upper half. An abdominal bruit or thrill may have been detected. The proximal aortic clamp is applied and the aorta opened in the usual fashion. The fistula is then oversewn from inside the aortic sac with a heavy monofilament suture. Temporary control can be gained by local digital pressure on the IVC above and below the fistula. No attempt must be made to separate the aorta from the IVC. The above description of the clinical presentation is well known, but many fistulae are incidental findings, only diagnosed when dark blood from the cava appears as the thrombus is lifted out of the aneurysm.

MIXED ANEURYSMAL AND OCCLUSIVE DISEASE

Although most elective aneurysm surgery is performed entirely within the abdomen, the presence of iliac occlusive disease may necessitate exposure of the groin to find suitable outflow vessels. Increased operative complexity increases the morbidity, but there is also increased mortality, perhaps to as much as 10%. The presence of occlusive disease indicates a higher risk of latent coronary, cerebral and visceral atheromatous disease and, therefore, an increased risk of perioperative myocardial and cerebral infarction and of renal failure.

Planning requires adequate arterial imaging, usually in the form of a CT angiogram. The aortic aneurysm replacement is combined with a bypass to the common, superficial or profunda femoral artery. As before, some thought must be given to the pelvic circulation at the end of the procedure. If there are no internal iliac vessels visible on imaging, and the IMA is patent, then this vessel may need reimplanting. If an IIA is patent and the external iliac artery is patent from the groin up, then retrograde perfusion can be expected to be sufficient (Figure 19.21). However, difficulties arise if the external iliac artery is occluded and both the IIAs (or the only remaining patent IIA) are perfused by patent common iliac arteries, which will be excluded by the bypass. In this situation, if the IMA is also chronically occluded, a jump graft may be needed to the IIA. However, if there is angiographic evidence of chronic occlusion of these vessels, or they exist on the angiogram as isolated segments, then special efforts to revascularise are not necessary, as collaterals will already have developed.



19.21 An inlay aortobifemoral graft for mixed aneurysmal and occlusive disease. The origins of the IMA and of the IIAs have been excluded by the graft. On the patient's right, the external iliac and common femoral arteries are occluded, the graft has been taken to the profunda femoris artery and no retrograde flow is possible. On the patient's left, the graft has been taken to a patent common femoral artery and pelvic perfusion can be maintained by retrograde flow up the left external iliac artery. ⏎

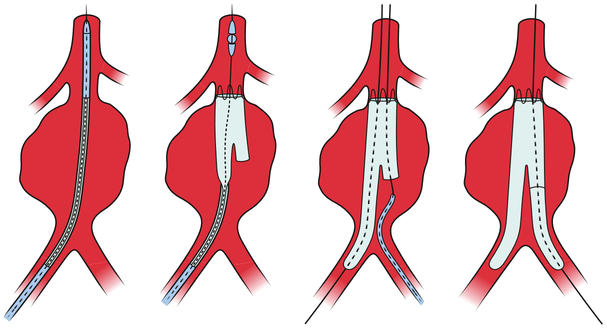
When surgery is undertaken for mixed aneurysmal and occlusive disease there are some modifications to the operation described above for simple aneurysmal disease. If a bypass to the femoral system is anticipated, it is usual to explore the groins before opening the abdomen. Once a suitable site for the distal anastomosis is confirmed, tunnels for the graft are formed. An index finger is gently inserted, nail down, in front of the common femoral artery and a space created into the pelvis. The surgeon must be aware of the deep circumflex iliac vein, which runs over the distal external iliac artery and is easily torn. If seen in the operative field, this vein must be ligated. Once this space has been fully opened to the limit of the finger, the tunnel is completed from above once the abdominal component has been completed. From inside, an index finger is gently advanced in front of the common iliac artery, pushing peritoneum and, more importantly, the ureter in front of the proposed tunnel. The two fingers will meet and a little, gentle, circular action of the fingertips may be required to break down the last intervening connective tissue. A long instrument is then passed up the tunnel and a nylon tape/rubber tube is pulled down to the groin wound. The tape is clipped and left *in situ* to ensure that the track can be found again when the time comes to pass the limbs of the graft down into the thigh. The tunnels are usually formed before administration of heparin and, therefore, before the proximal anastomosis has been performed. The retractors from the groin wound are removed and the cavity is packed with moist gauze until ready for anastomosis.

Proximal and distal clamps are then applied and the aneurysm sac is opened as described above. After completion of the proximal anastomosis, each limb of the graft is brought through its respective tunnel and anastomosed end to side onto the appropriate segment of femoral artery. A final consideration is closure of the proximal ends of the iliac segments. The common iliac arteries are usually clamped or occluded by balloons, but after the top end of the graft is secured, the common iliac arteries must be sutured closed. This requires a double row of non-absorbable, heavy, monofilament sutures, and haemostasis must be checked at the end of the procedure. Even in the case of chronic total occlusion of the iliac segment, there remains a chance of back-bleeding when the clamps are released at the completion of the distal anastomoses.

ENDOVASCULAR ANEURYSM REPAIR

The first EVAR, by Parodi et al. in 1991, resulted in a revolution in the management of AAA.[31] This technique relies on exclusion of the aneurysm rather than replacement. Advantages include reduced morbidity and mortality rates and a shorter postoperative stay in hospital. Disadvantages include cost, the now receding concerns over the reliability of new technologies, the need for long-term device surveillance and the high incidence of often minor problems that nonetheless require reintervention.[32] Preoperative assessment of the aneurysm morphology and the aortic dimensions at the neck and distally are crucial. A variety of devices and systems are available. The procedure is undertaken with digital subtraction angiography (DSA). In summary, following cannulation, an initial angiogram is performed, demonstrating the origins of the renal arteries and confirming the morphology at the neck of the aneurysm. The main body of the stent graft and ipsilateral limb are then delivered and deployed, starting from below the lowest renal artery, followed by the contralateral limb (Figure 19.22). It is routine to perform balloon angioplasty to the stent graft landing sites in order to mould the device and improve conformity to the native vessels.

Initially, this technique was limited to the infrarenal aorta, but with the accumulation of experience and the evolution of stent graft technology, including suprarenal fixation and fenestration, the boundaries are extending. It is beyond the scope of this chapter to discuss this topic in much more detail, not least because the exact sequence of deployment is device specific and each has its own idiosyncrasies.



19.22 EVAR. The stent graft is deployed through the right common femoral artery, starting from below the lowest renal artery and extending into the right common iliac artery. The left common femoral artery is used to cannulate the left (short) limb of the graft and a guide wire is placed. The second component is delivered over this to end in the left common iliac artery. ⏎

AORTIC GRAFT COMPLICATIONS

The true rate of graft complications is not known, but it is estimated that approximately 1–2% of aortic grafts will become infected. This may present as a systemic illness due to sepsis or as a local graft problem, whether in the form of a pseudoaneurysm or the development of a sinus discharging pus from an anastomotic site (most frequently in the groin). More dramatic manifestations include fistula formation or haemorrhage due to anastomotic disruption. Aortoenteric fistulae are considered part of the spectrum of infective complications; the graft is inevitably infected at the point at which the condition becomes apparent.

Diagnosis of graft infection is often difficult. If the patient presents with torrential gastrointestinal bleeding, sepsis or an obvious septic focus and a CT scan demonstrates perigraft fluid, ectopic gas or intravenous contrast medium in the bowel lumen, the diagnosis is simple. However, it is much more difficult to exclude or confirm graft infection in a patient with more insidious symptoms, for example weight loss, lethargy, pain or gastrointestinal blood loss. CT scans may show focal bowel thickening, inflammation of the perigraft tissues, vertebral osteomyelitis, hydronephrosis or minor anastomotic dilatation, but none of these alone will secure a diagnosis. Labelled white-cell scans and MRI have a role, but reported sensitivities vary widely. Upper and lower gastrointestinal endoscopy is often unhelpful unless there is active bleeding, but an ulcer in the third or fourth part of the duodenum should be treated with suspicion. The patient may present many years after the original surgery, and the bacteria implicated range from a destructive *Staphylococcus aureus* to a low-virulence *Staphylococcus epidermidis.*

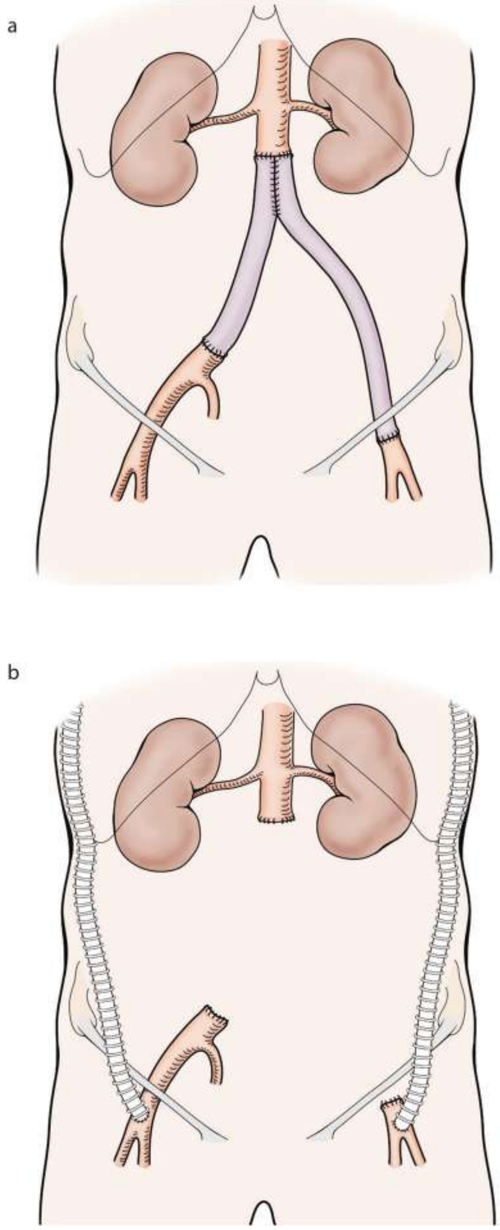
Operatively there are two aims: (1) the excision of infected material and septic foci and (2) the maintenance of tissue perfusion. The mortality of surgery for infected aortic prostheses is reported at up to 50%, with major amputation rates in the survivors also approaching 50%. A major concern is recurrent infection in a newly implanted prosthesis, by either direct or haematogenous seeding.

Occasionally, a local procedure can be performed. The limb of an infected, aortic bifurcated graft can be excised, and this may be sufficient if the patient presented with a chronic local problem. Some surgeons advocate that, if any part of a graft is infected, it must be assumed that the whole is affected. Pragmatically, an older or frail patient may survive a local graft excision and, if the infection is low grade, there may not be a further problem within that patient's lifetime.

There are three key areas to consider preoperatively:

1. The method of reconstitution of flow must be decided – anatomic or extra-anatomic (Figure 19.23). The extra-anatomical route has the possible advantage of lowering the risk of infection in the new graft. Axillofemoral bypass is described in the section 'Options in limb salvage surgery'.
2. The material for the replacement conduit must be chosen – prosthetic material, prosthetic material with microbial retardant adjuvant (e.g. rifampicin or silver coating) or autologous vein. The long saphenous vein (LSV) is not ideal for this purpose, but a graft can be fashioned using the deep venous system of the thigh. Symptomatic chronic venous insufficiency affects only a minority of patients if the profunda femoris vein is left intact. A small number of surgeons have reported work using arterial allografts.
3. Consideration should be given to whether the procedure can be staged. This is more likely to be possible if the original indication was for occlusive disease many years before and the collaterals are sufficiently well developed. After excising the infected material and closing the defects in the native vessels, a period of careful observation may demonstrate viable limbs fed by collaterals. The graft has been excised and no replacement conduit has been inserted. A delayed replacement bypass can be considered if a limb remains viable but still ischaemic.

If an infected aortic graft is excised and is followed by an extra-anatomical replacement graft, the stump of the proximal native aorta must be closed. This is a vulnerable end closure of a large artery that has a wall made friable by both the underlying degenerative disease and the infection. Closure is usually in two layers; monofilament mattress sutures are usually recommended before the aortic clamp is released, followed by a further continuous suture. The anterior spinal ligament can be mobilised to cover the aortic stump. Distally, the iliac stumps must also be oversewn (Figure 19.23b). The exact sequence of events is variable. The risk of stump blowout is always present in spite of these manoeuvres and best surgical



19.23 Reconstruction for infected aortic grafts. (a) The infected graft has been excised and replaced with a deep vein graft to the common iliac artery (on the patient's right) and to the common femoral artery (on the patient's left). (b) After excision of the infected aortic graft, the aortic stump and the right common iliac artery have been oversewn. Bilateral axillofemoral grafts can restore distal perfusion. ⏎

technique. Haematogenous seeding and cross-contamination are major hazards regardless of whether the extra-anatomical bypass is done before or after the excision. Opening the axillofemoral component before the aortic flow is closed may lead to occlusion of the new conduit because of competitive flow. There are no solutions without drawbacks. The procedure may be done in a staged manner (bypass first followed by graft excision) to shorten the length of procedure.

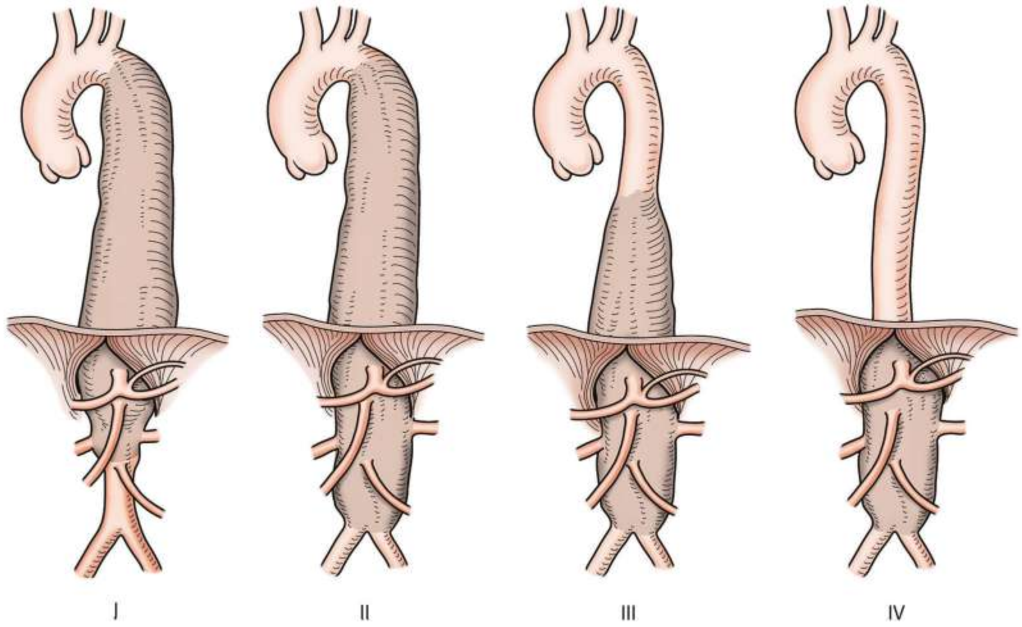
THORACOABDOMINAL ANEURYSMS

These aneurysms are subdivided into types I to IV and are illustrated diagrammatically in Figure 19.24 (Crawford classification).[33] The nomenclature is superficially confusing, as type IV aneurysms are still confined to the abdominal aorta. However, the additional technical challenges that they pose justify their inclusion with the other thoracoabdominal aortic aneurysms (TAAAs).

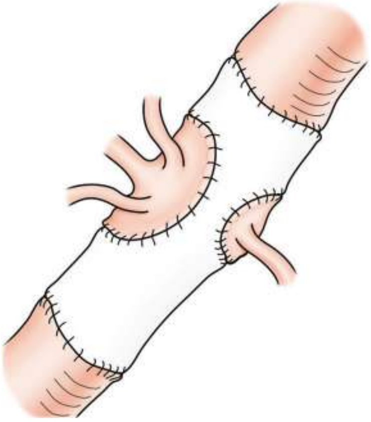
The surgery for any of these aneurysms is a very major undertaking, with significant mortality and morbidity. In many older and frail patients, surgical intervention will not be justified. The access required to the chest is in itself associated with significant postoperative respiratory sequelae. However, cross-clamping above the visceral vessels is also responsible for the increased complication rate. The ischaemia reperfusion effect is a major insult, so immediate or delayed cardiac complications are frequent. Other specific organ complications, more frequent with the extended nature of TAAA repair, include renal failure, spinal cord ischaemia and coagulopathy. Temporary shunts to maintain distal blood flow have been employed in attempts to reduce left ventricular strain, acute tubular necrosis and paraplegia, but these have not been universally successful. Left heart bypass is also used to maintain distal perfusion if segmental clamping is employed. The proximal anastomosis can be performed with clamps on the aorta at the diaphragm and at the junction of the aortic arch and descending aorta. Meanwhile, inflow from the left heart bypass to a femoral artery maintains perfusion to the lower half of the body by retrograde flow.

Although the aneurysm sac is opened and the top end of a long prosthetic graft is secured in place in a similar fashion to that employed in an infrarenal aneurysm repair, there is the additional challenge of restoring inflow to the important branches of the thoracic and abdominal aorta. Intercostal arteries may have to be reimplanted to safeguard the spinal cord, followed by reimplantation of renal and visceral arteries. Patches of native aorta are cut to encircle the origins of the arteries and these patches are sewn into similar-sized holes cut in the graft (Figure 19.25).

Customised endovascular stents have been developed for the treatment of TAAAs, with fenestrations and branching systems. Endovascular stent treatment can also be combined with open visceral and renal revascularisation in a hybrid procedure to exclude the aneurysm and reroute visceral perfusion.



19.24 Thoracoabdominal aneurysms are classified into four types. Type I is a thoracic aneurysm that extends down to involve the origins of the visceral vessels. Type II is a diffuse aneurysm involving the whole of the thoracic and abdominal aorta. Type III involves the whole abdominal aorta but only the lower thoracic aorta. Type IV involves the suprarenal portion of the abdominal aorta, but the aorta is normal above the diaphragm. ⏎



19.25 Discs of native aorta are cut to include the origins of the renal and visceral arteries. These discs are anastomosed into holes cut in the graft. ⏎

OCCLUSIVE DISEASE OF THE VISCERAL ARTERIES

RENAL ARTERY ISCHAEMIA

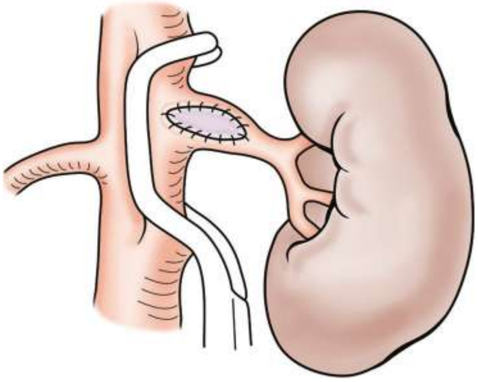
Occlusive disease of the renal arteries may be atherosclerotic or the result of conditions such as fibromuscular dysplasia. The renal ischaemia may result in deterioration of renal function or may cause renovascular hypertension by altering the renin/angiotensin homeostatic balance. Renal revascularisation, whether surgical or radiological, now has very few clear indications, namely recurrent (flash) pulmonary oedema in the presence of bilateral renal artery disease, a tight renal stenosis to a single functioning kidney and renovascular hypertension refractory to medication and associated with deteriorating renal function.

Endarterectomy

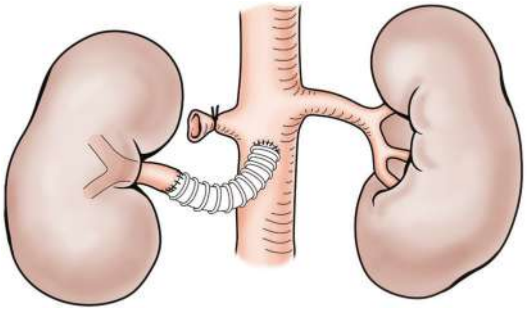
A transaortic renal endarterectomy, as illustrated in Figure 19.26, is a satisfactory approach that is usually possible without a full aortic cross-clamp. The incision is transverse and extends into the renal artery. Closure is with a vein patch. Transaortic renal endarterectomy is useful for ostial disease, but this condition is probably better treated using endovascular techniques by angioplasty and stenting.

Bypass

The choice between infrarenal and suprarenal aorta as the donor site depends mainly on the distribution of aortic atheromatous disease. An end-to-side aortic anastomosis is best performed with a side clamp, but, as this requires a soft vessel, a cross-clamp is needed for the usually thickened and atheromatous aorta. The distal anastomosis of graft to native renal artery beyond the stenosis may be end-to-side or end-to-end (Figure 19.27).



19.26 A renal endarterectomy. A side clamp is maintaining distal flow. Closure is with a vein patch. ⏎

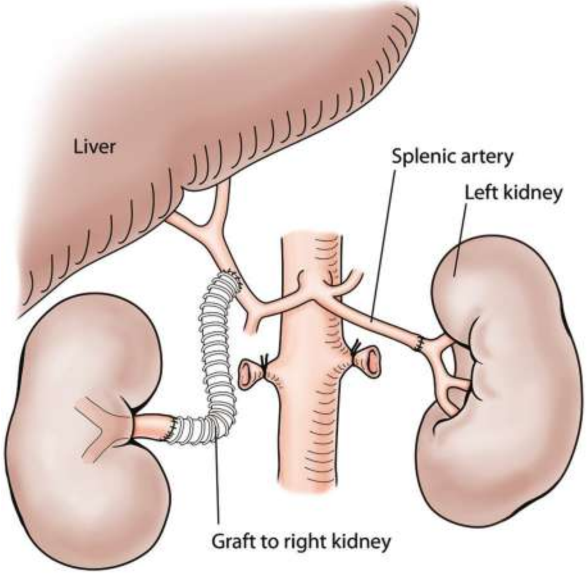


19.27 Revascularisation of the kidney with a graft from the infrarenal aorta. This is an end-to-side anastomosis onto the aorta, but an end-to-end anastomosis to the renal artery distal to the stenosis. ⏎

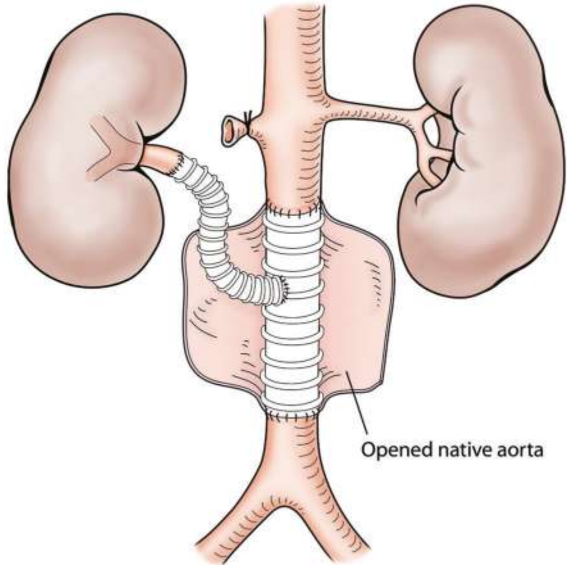
When the abdominal aorta is too heavily diseased for a graft to be taken from the region of the kidney, there are several alternatives. Although the iliac arteries are frequently similarly affected, a soft area can often be found to allow a long graft to be taken up to the renal artery. Alternatively, a graft can be taken from the hepatic artery or, after a splenectomy, the splenic artery can be anastomosed end-to-end to the renal artery (Figure 19.28). A further option is to auto-transplant the kidney into the iliac fossa. This will require an arterial and a venous anastomosis, but the ureter, after mobilisation, can be left undisturbed.

Simultaneous aortic and renal artery reconstruction

This more major procedure, with a significantly higher mortality rate, may be considered if open procedure is required with indications for both aortic and visceral artery reconstruction (Figure 19.29). Generally, it would be safer to treat the visceral artery pathology using an endovascular approach followed by an open aortic procedure separately. If an endovascular



19.28 Alternative donor arteries can be used to revascularise a kidney. Right kidney: a graft has been taken from the hepatic artery. Left kidney: the spleen has been removed and the splenic artery itself used for an end-to-end anastomosis. ⏎

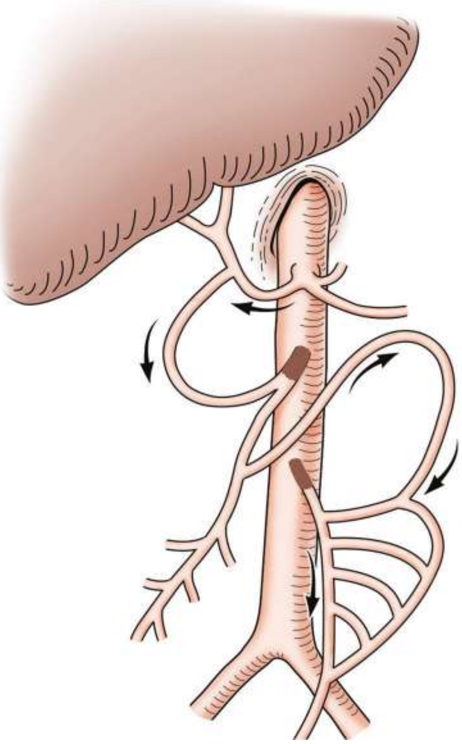


19.29 Right renal revascularisation has been combined with an infrarenal aortic tube graft. ⏎

approach is used, the surgeon needs to be careful not to crush the stent during retraction and clamping.

MESENTERIC ISCHAEMIA

Acute mesenteric ischaemia, presenting as an intra-abdominal emergency with ischaemic or infarcted bowel, is also discussed in Chapter 13. However, there is considerable overlap between the pathology of acute and chronic presentations. An appreciation by the gastrointestinal surgeon of the causes and treatment of bowel ischaemia is essential if a patient is to be offered the chance of reperfusion and salvage of sufficient bowel to avoid lifelong parenteral nutrition. Acute presentation includes pain out of proportion to clinical findings; this may be the result of an embolus to the SMA, which can be treated by endovascular methods (aspiration/lysis) or embolectomy, as described in Chapter 13. More frequently, the lesion is thrombosis on a pre-existing ostial lesion.



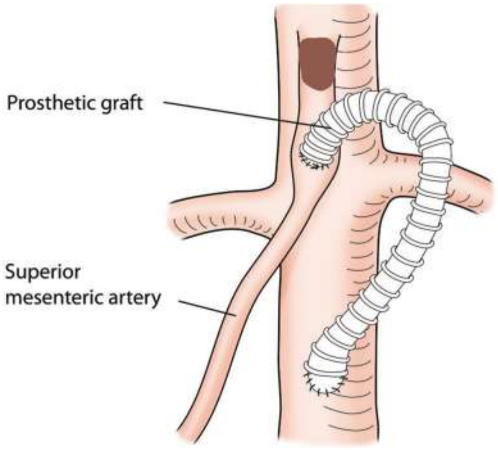
19.30 Extensive collateral circulation allows the whole gut to be perfused through a single patent visceral artery. ⏎

Chronic mesenteric ischaemia classically presents with non-specific post-prandial abdominal pain and significant weight loss. Initially, anatomical communication between the three visceral arteries provides adequate alternative routes for perfusion (Figure 19.30). Classically, at least two of the three mesenteric vessels are occluded, but this is not always the case. Isolated SMA occlusion can present with gut ischaemia. Patency of the IIA and a history of previous bowel resection are also important as collateral circulation may have been interrupted. Once symptomatic mesenteric ischaemia develops, revascularisation must be considered. An ultrasound Doppler can provide information for diagnosis, but a CT angiogram is the standard for evaluation and intervention.

With the evolution of available endovascular techniques, the first choice for revascularisation is usually endovascular; sometimes a combined approach (hybrid) is appropriate.[34] Stenosis may be primarily at the origin of an artery, and this ostial disease in the SMA is a good target for angioplasty and stenting. However, the diaphragmatic crura make the coeliac trunk more prone to reocclusion than the SMA, even when the vessel is stented. Despite this, percutaneous intervention remains a reasonable first option for this vessel. Extensive or more distal disease within the mesenteric vessels invites a surgical approach. Decisions must be made regarding the site for inflow and the target vessels for reperfusion. The type of conduit and the route of the conduit tunnel must also be chosen. The IMA is rarely grafted, except following aortic surgery; the usual target vessels are within the SMA and coeliac systems.

In a purely elective setting, two-vessel grafting is probably preferable. A prosthetic bifurcated graft from the common or external iliac artery is tunnelled through the retroperitoneum in front of the aorta. One limb is then passed up through the small bowel mesentery to the SMA, with a long ‘lazy’ C loop, and the other limb is brought up to the coeliac system behind the pancreas. Figure 19.31 shows such a graft taken to the SMA alone. The choice of outflow vessels is based on the preoperative angiograms, but also to a large extent on which patent vessels are accessible. If there are no inflow sites distally, the aorta just proximal to the diaphragm is an alternative.

In an emergency, the situation is complicated by the need to excise non-viable bowel, or the likelihood that this may be required at a second laparotomy (see Chapter 17). The chance of graft infection due to translocation is high, in which case prosthetic material could be contraindicated and vein grafts are required. A short GSV vein graft or direct side-to-side anastomosis between the posterolateral wall of the SMA and the anterior wall of the aorta may be required. It is common practice to reperfuse the SMA alone in an emergency. In some acute circumstances, following an angiogram, a hybrid procedure may be appropriate: endovascular revascularisation can be followed by a laparotomy to inspect and manage any necrotic bowel. Additionally, it should also be remembered that some SMA lesions are more easily dealt with by retrograde angioplasty from inside the abdomen once it has been confirmed that there is some hope of salvage.[35]



19.31 A retrograde bypass graft from the aorta to the SMA. The wide curve reduces the risk of kinking and aligns the flow with the recipient vessel. ⏎

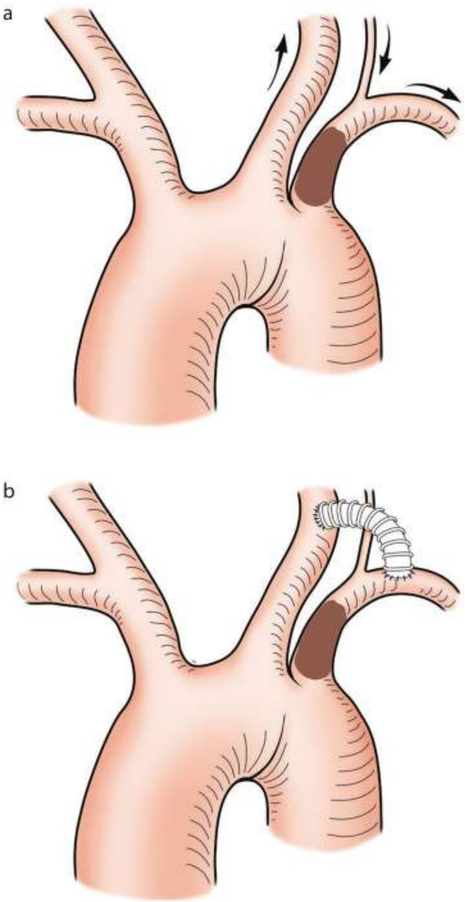
Access

The visceral arteries are usually isolated via a transperitoneal anterior abdominal approach. The *coeliac artery* is reached by an incision into the lesser sac through the lesser omentum. The aorta emerges into the abdomen just to the right of the oesophagus, which is easily identified if a nasogastric tube has been passed. The origin of the coeliac artery is very close to the diaphragm, and additional aorta above it can be exposed by an incision in the right crus of the diaphragm. The origin of the SMA can be reached by the same approach as that required for the coeliac artery, but it can also be exposed several centimetres from its origin, where it emerges from below the lower border of the pancreas. The vascular bundle can be identified between a finger and thumb placed either side of the root of the small bowel mesentery.

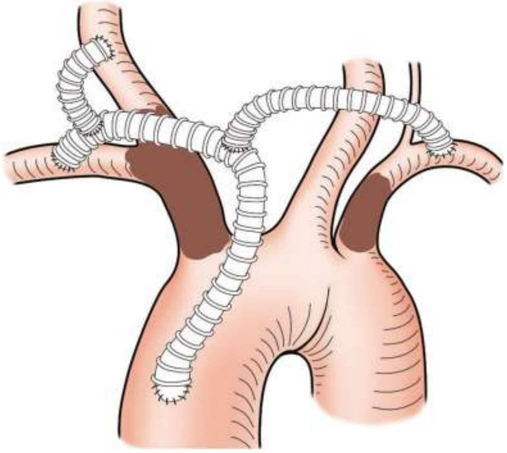
The alternative posterior approach to all three arteries relies on a medial visceral rotation of the splenic flexure of the colon, spleen and tail and body of the pancreas.

DISEASE OF THE ARTERIES OF THE AORTIC ARCH

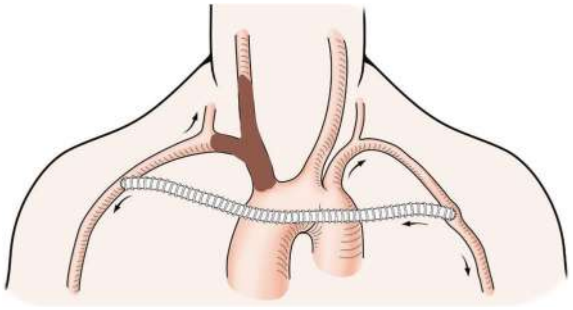
Although stenoses of the roots and proximal portions of the large branches of the aortic arch can occur in atheromatous disease, (Takayasu’s) arteritis is an alternative underlying pathology. Patients with carotid occlusion may present with neurological symptoms, but many are asymptomatic. Those with subclavian occlusion may present with exercise-related symptoms in the upper limb muscle groups or, rarely, critical ischaemia. However, they may also present with neurological symptoms, particularly dizziness, when the only perfusion of the limb is from retrograde flow down the vertebral artery, with subsequent deleterious effects on cerebral perfusion when exercising the upper limb (Figure 19.32a). This is known as *subclavian steal phenomenon* and is a much more common indication for intervention.



19.32 (a) The proximal subclavian occlusion has resulted in 'subclavian steal', in which the upper limb perfusion is dependent on retrograde flow down the vertebral artery. (b) Revascularisation with a bypass graft from the carotid artery. ⏎



19.33 A graft from the thoracic aorta to the arteries of the aortic arch, which are occluded near their origins. ⏎

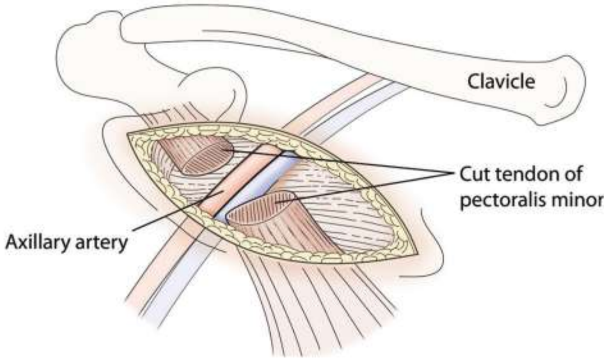


19.34 A bypass graft from one axillary artery to the other to restore upper limb perfusion. ⏎

Symptomatic disease is relatively rare, and an endovascular approach is the first line of management. Surgery is therefore performed relatively infrequently, and patients who do require operations are usually referred to surgeons with a special interest. However, the principles are similar to other reconstructive challenges. When several vessels are involved, inflow may have to be taken from the aortic arch (Figure 19.33) but, if the stenosis affects only one or two large arteries, extrathoracic bypass techniques will be practical. Two such grafts are illustrated in Figures 19.32b and 19.34. In Figure 19.32b, a graft has been taken from the CCA to the patent portion of the ipsilateral subclavian artery distal to the obstruction. The supraclavicular approach, which allows simultaneous access to both of these arteries, is described in the section 'Surgical approach' under 'Thoracic outlet syndrome' earlier in this chapter and is illustrated in Figures 18.6, 19.8 and 19.9. Figure 19.34 illustrates a bypass from a patent axillary artery to a contralateral axillary artery, which has an inflow obstruction. A bilateral infraclavicular approach, as described for an axillo-bifemoral bypass and illustrated in Figure 19.35, is used. The graft is tunnelled subcutaneously across the anterior chest wall.

OPTIONS IN LIMB SALVAGE SURGERY

The options for limb ischaemia include a conservative approach based on best medical therapy, an endovascular approach, a reconstructive surgical approach, amputation if there is no possible reconstructive option (see Chapter 20) or a palliative approach, accepting that the ischaemic limb is a manifestation of end-stage cardiovascular or coexisting malignancy. Medical treatment comprises antiplatelet therapy, the introduction of a statin and optimisation of antihypertensive therapy. Diabetes should be excluded and, if present, an appropriate regime for glycaemic control should be introduced. Advice and support should be given regarding cessation of smoking, and regular exercise should be advocated.



19.35 A small transverse infraclavicular incision will provide good access to the axillary artery for an axillofemoral bypass. ⏎

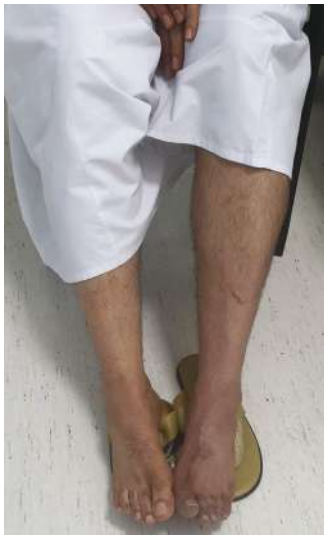
Endovascular intervention has opened new avenues for limb salvage. Thrombolysis, either within a native vessel or, most effectively, within a graft, is an alternative to surgery in acute limb ischaemia. Angioplasty, with or without stenting, offers many advantages over surgery, particularly in the aortoiliac segment. Frequently, endoluminal procedures alone are sufficient to salvage a limb. Percutaneous procedures can also be used in conjunction with reconstructive surgery to optimise inflow and allow a crossover graft or a femoropopliteal graft to function. Angioplasty may also salvage a failing graft.

ACUTE LIMB ISCHAEMIA

In the absence of protective collaterals, sudden occlusion of an artery can present as acute limb ischaemia. Limb salvage will usually require emergency intervention to restore distal perfusion. Attempts should not be made to restore the circulation to a limb that is non-viable; not only is this futile, but products from the dead tissue enter the circulation, causing systemic insult including biochemical derangements. This reperfusion injury results in metabolic acidosis, hyperkalaemia, myoglobinuria leading to cardiac arrhythmias and renal failure. Life-saving urgent amputation is occasionally required but, in some patients, acute limb ischaemia is a terminal event and palliative care is more appropriate.[29]

DIAGNOSIS AND ASSESSMENT

The classical presentation of acute limb ischaemia is with the six Ps: a sudden onset of pain, followed by perishing cold, pallor, paraesthesia and ultimately paralysis, associated with a pulseless limb (Figure 19.36). The marble white leg is not seen universally, as venous reflux or a trickle of blood via collaterals can colour the skin and confuse the situation. Handheld Doppler assessment is very helpful, as is a clinical comparison with the pulse pattern of the contralateral limb. When the diagnosis has been established, anticoagulation is commenced with 18–20 IU/kg of unfractionated heparin. Access to theatre is not always as swift as needed, and heparin prevents thrombus extension. While waiting, therapeutic anticoagulation must be initiated with unfractionated heparin.



19.36 A patient presenting with a left acute limb ischaemia. Note the bluish discoloration that is typical of this presentation. ⏎

Consideration of the underlying pathological process is important. Acute ischaemia may result from embolism or thrombosis *in situ* due to underlying atheroma, aneurysm, or a new or acquired thrombophilia. The mechanism of the acute occlusion will influence the surgical salvage strategy, but the value of investigations to clarify this must be balanced against the resultant delay, during which the potential for a good functional recovery is deteriorating. A difficult balance needs to be found if there is suspicion of underlying arterial disease. In this situation, several rescue strategies may need to be considered, which makes good preoperative imaging highly desirable. Rapid symptomatic deterioration suggests that the patient has little in the way of protective collaterals and that the limb is imminently threatened. Likewise, sensorimotor impairment increases the urgency of the situation. Consideration should therefore be given to urgent exploration with a view to thromboembolectomy and on-table imaging.

If the onset of symptoms has been more insidious, with a pre-existing history of claudication or even rest pain, reinforced by evidence of contralateral peripheral arterial occlusive disease, preoperative imaging is essential. In this context, there may be a role for thrombolysis as the first line in treatment, followed by

Table 19.1 The Rutherford classification of acute limb ischaemia

Category	Description/Prognosis	Findings		Doppler signal	
		Sensory loss	Muscle weakness	Arterial	Venous
I. Viable	Not immediately threatened	None	None	Audible	Audible
II. Threatened					
a. Marginally	Salvageable if promptly treated	Minimal (toes) or none	None	Inaudible	Audible
b. Immediately	Salvageable with immediate revascularisation	More than toes, associated with rest pain	Mild, moderate	Inaudible	Audible
III. Irreversible	Major tissue loss or permanent nerve damage inevitable	Profound, anaesthetic	Profound, paralysis	Inaudible	Inaudible

either angioplasty or definitive surgery. The groups of patients for whom lysis may be more suitable include those with graft occlusion, those with multiple emboli arising from a popliteal aneurysm and those in whom there is a specific underlying anatomical abnormality, such as popliteal artery entrapment syndrome. In each of these scenarios, lysis can be used to retrieve a difficult ischaemic situation and allow definitive corrective surgery at a later date. Surgeons must be wary of a patient presenting with a complication of a thrombosed or embolising popliteal aneurysm (see the later section on 'Popliteal artery aneurysms'). Some 50% of patients presenting in such a way will ultimately lose their leg due, at least in part, to a failure of timely diagnosis.

The limitation of thrombolysis in acute limb ischaemia is the delay after the start of treatment before there is any improvement in perfusion. There is often even an initial worsening of both the symptoms and the signs of ischaemia in the first few hours. This makes it an unsuitable treatment when the initial assessment indicates limb loss within 4–6 hours unless the circulation is restored. The Rutherford classification of acute limb ischaemia (Table 19.1) provides a guide to severity of ischaemia and urgency of treatment.[36]

THROMBOEMBOLECTOMY

The two most common sites for this procedure are the common femoral artery in the groin and the distal brachial artery just above the elbow. In both cases, this represents a site of arterial bifurcation where an embolus may lodge. Usually, there is extension of thrombus proximal and distal to the occlusion. All thrombus must be removed before perfusion can be restored. The diagnosis of embolus is more common in the upper limbs, as they are less affected by atherosclerotic PAD. In the lower limbs, there is a greater likelihood of an iliac or superficial femoral artery thrombosis *in situ*. Thrombectomy may be successful in this situation but, if it does not succeed in restoring distal perfusion, there may be a need for a salvage bypass.[37]

Brachial embolectomy

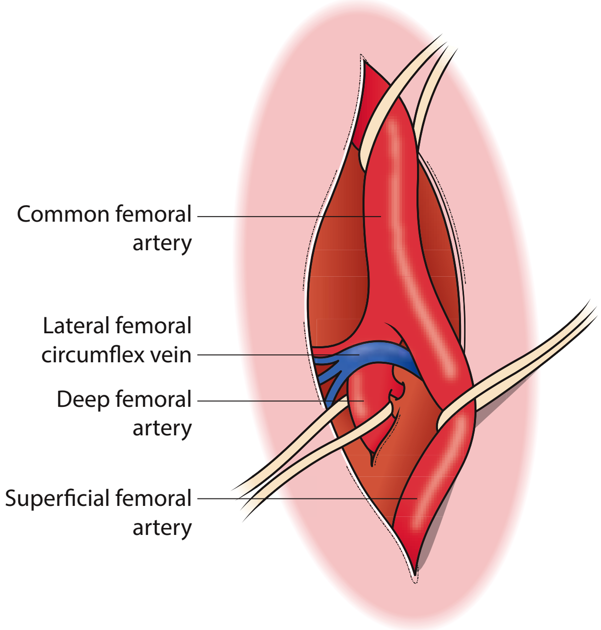
Many surgeons will treat brachial emboli conservatively with anticoagulation alone, especially in the frail group of patients in whom this condition often presents, but reviewing every few hours is an essential component of conservative management. Inadequate return of power to the dominant hand or worsening ischaemia are the most frequent indications for a delayed salvage procedure.

Embolectomy can be performed under local anaesthesia in a cooperative patient, and most patients tolerate this well, but it is advisable to have an anaesthetist present, as an acute deterioration can occur during the procedure and sometimes some sedation or conversion to a general anaesthetic is required. Often, a pulse can be felt all the way down the brachial artery to just above the bifurcation in the antecubital fossa. If a pulse is not felt over the brachial or axillary arteries, preoperative imaging is strongly indicated.

The arm, positioned in abduction and lateral rotation, is supported on an arm board. The skin should be prepared from the shoulder to the wrist, and the hand is draped in such a way as to allow assessment of the return of perfusion (a clear bowel bag is useful if available). A lazy-S incision is made from just medial to the distal portion of the biceps muscle, over the tendon and then down onto the forearm. After incising the skin, a few subcutaneous veins are usually encountered; these should be divided between ties or pushed to the side with a self-retainer. The brachial artery lies between the biceps tendon and the median nerve and deep to the bicipital aponeurosis. The latter structure can be incised to allow further exposure. The brachial artery is slung and this can be used to retract it forwards to find the bifurcation. Both the radial and the ulnar arteries must be slung to allow proper clearance of these vessels. The interosseous artery often arises close to or at the bifurcation and may produce troublesome back-bleeding.

The arteries are clamped and a transverse arteriotomy is performed about 1 cm proximal to the bifurcation. A Fogarty balloon is passed, proximally first and then distally, down both the radial and the ulnar arteries. Good inflow must be established, as well as good back-bleeding from each of the distal vessels. The Fogarty catheter must be used with care, as discussed in Chapter 18. It is important not to overinflate the balloon and to adjust the pressure with care as resistance changes: the pressure can be gauged through the thumb depressing the syringe plunger.

Completion angiography is desirable but not compulsory. An indication for completion angiography could be if distal pulses are not palpable. A residual thrombus is often a cause for rethrombosis of the reperfused blood vessel. Ideally, this is achieved with a C-arm image intensifier system. Modern machines can produce subtraction images in theatre. Once satisfied, the arteriotomy is closed with interrupted 5/0 or 6/0 monofilament sutures, inserted so that the needle passes from inside to outside the artery on the distal side of the arteriotomy to ensure that intimal flaps are not lifted during closure. Intimal flaps raised during closure can result in occlusion of the artery and can extend as a dissection flap further down the vessel.



19.37 The common femoral artery and superficial femoral artery are looped first, then, by medial retraction, the profunda femoris artery can be identified. Note the lateral femoral circumflex vein crossing the first part of the profunda femoris artery. ⏎

Femoral embolectomy

Most femoral explorations can be performed under local anaesthesia. However, a number of cases may require fasciotomies or, occasionally, a bypass, so it is essential that the anaesthetist has seen the patient preoperatively. The groin should be shaved and consideration must be given to the possible need for a crossover graft to provide adequate inflow from the opposite side. The skin of the limb is prepared down to the ankle, after which the foot is placed in a transparent bag. The anterior superior iliac spine and the pubic tubercle should be left visible as useful groin landmarks. The femoral artery emerges underneath the inguinal ligament medial to the midpoint of the inguinal ligament and medial to the deep inguinal ring, halfway between the anterior superior iliac spine and the symphysis pubis. The femoral vein lies medial to the femoral artery. The common femoral artery is approached via a vertical or oblique incision through the skin and the subcutaneous fat. Scarpa's fascia is incised and, deep to this level, veins and lymphatics must be divided between ties as encountered. The lymphatic channels are commonly visible just anterior to the common and superficial femoral arteries. The dissection over the superior part of the incision is carried down to the inguinal ligament. Further dissection down to the femoral artery can be guided by pulsations if present. If the femoral pulse is not palpable, the occluded artery can be identified by rolling a finger over the area. The common femoral artery is slung at the level of the inguinal ligament and tapes are then also passed around the superficial femoral artery and profunda femoris artery. Taping the common femoral artery and the superficial femoral artery first and bringing them under tension medially allows easy identification of the origin of the profunda femoris artery. Care must be taken not to damage the lateral femoral circumflex vein when dissecting the artery (Figure 19.37). The posterior aspect of the bifurcation must be carefully inspected to avoid missing a 'first perforating branch' of the deep system. Anatomy is variable and the lateral or medial circumflex arteries may arise from either the common femoral or the profunda femoral artery.

Careful attention must be given to the quality of the vessels. The superficial femoral artery may be chronically occluded, the origin of the profunda may be narrowed or there may be a posterior plaque running down into the common femoral artery from the external iliac artery. These features will influence placement of the arteriotomy and clamps. The common femoral artery is opened transversely if the vessels are large and disease free or if the common femoral disease is confined to a modest posterior plaque. An oblique arteriotomy down into the profunda femoral artery is best if the superficial femoral artery is chronically occluded and the origin of the profunda is hard and therefore in need of patch angioplasty closure. If in doubt, a longitudinal arteriotomy, with planned patch closure, is perhaps the best incision to keep options open. However, a transverse arteriotomy can be converted into a diamond opening to allow a common femoral endarterectomy, patch closure or the anastomosis of a bypass graft.

Inflow must be established first. The iliac system is swept with a large (size 4 or 5) Fogarty catheter. Good inflow, once gained, must be protected by flushing dilute heparinised saline solution (2,000 IU heparin in 500 mL saline) up the iliac system. Occasionally, inflow cannot be established and, at this stage, consideration must be given to a salvage extra-anatomical bypass or endovascular intervention.

Once inflow is established, attention is turned to the distal circulation. A size 3 Fogarty catheter is passed down the superficial femoral artery. In the case of a classic embolus, the major fragment will be found on opening the common femoral artery, but there will be smaller fragments and a ribbon, often an arterial cast, of propagated thrombus down the superficial and profunda femoral arteries. Keep passing the catheter up and down until there is no further return of thrombus and good back-bleeding: the catheter should have been passed to at least 40 cm down the artery. Often, if the thrombus is acute, the Fogarty catheter can be passed up to 70 cm. In this scenario, the catheter goes straight into the peroneal artery, as it offers the most in-line flow. These distal vessels should also be generously flushed with heparinised saline. Completion angiography is desirable, particularly if the clinical result of reperfusion is poor or if the catheter cannot be passed beyond the adductor hiatus. It may be that there is chronic occlusive disease with a stenosis or occlusion in the femoropopliteal segment, or the thrombus may be strongly adherent to the vessel wall. Alternatively, there may be a slightly unusual cause for acute ischaemia, for example a thrombosed popliteal aneurysm or, very rarely, an acute presentation of an entrapment syndrome. In some theatres where there is no access to a C-arm facility with image intensification, clinical assessment following closure of the arteriotomy is all there is to rely on. Watch for reperfusion of the foot with a marked hyperaemia. An awake patient will often report a return of feeling, movement and warmth.

If thrombus cannot be cleared from the distal circulation, intraoperative intra-arterial thrombolysis may be considered. Tissue plasminogen activator (t-PA) can be administered directly into the artery. The usual dose is 10 mg made up to 20 mL and instilled for 20–30 minutes before repeating the angiogram. If there is a chronic superficial femoral artery block, collaterals may be well developed. In this situation, clearance of both the acutely blocked iliac system and the common and profunda femoral arteries may be sufficient to restore perfusion to the limb. It is worth closing the arteriotomy and watching what happens to the foot. A patch angioplasty of a narrowed profunda origin may be sufficient to prevent rethrombosis.

Sometimes, a salvage bypass is required, as is performed for chronic ischaemia as described below. Fasciotomies (see Chapter 20) may also be indicated, especially if there was marked calf tenderness or sensorimotor impairment preoperatively. However, hard and fast rules on the need for fasciotomies are very difficult to define. Fasciotomies are not a local anaesthetic procedure and the likely need for them is an indication for a general anaesthetic. Thought should be given preoperatively to these possibilities, and the patient should be consented appropriately.

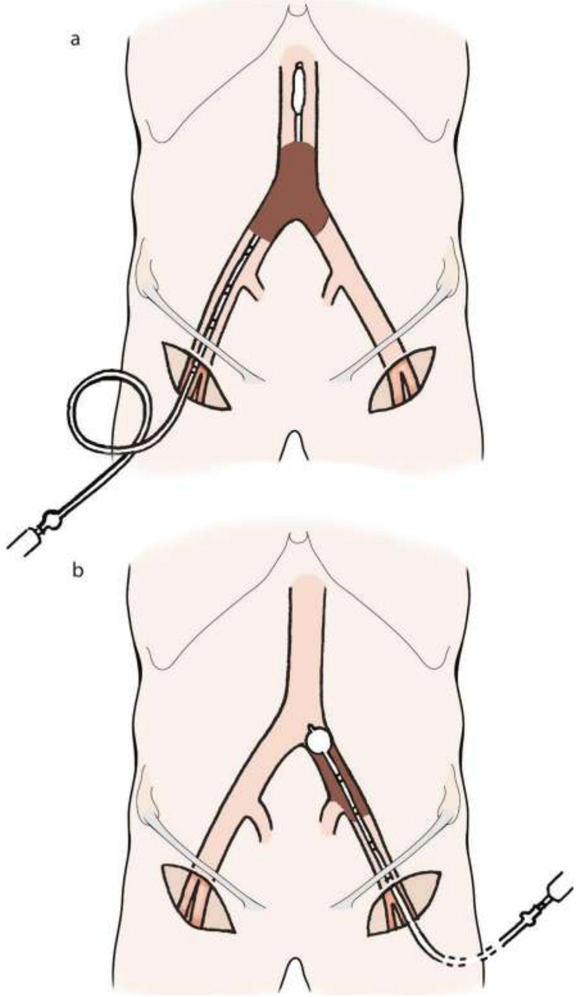
Saddle emboli

This is the situation in which a large embolus lodges in the aortic bifurcation, rendering both lower limbs acutely ischaemic. The principle differential diagnoses are of acute *in situ* thrombotic aortic occlusion and acute spinal cord ischaemia or compression. This highly lethal condition is often missed on presentation, especially if the presenting complaint is paraplegia. Diagnosis can be confirmed by CT angiography. It may be possible to clear the embolus by embolectomy via bilateral common femoral access, as illustrated in Figure 19.38, but salvage may require axillofemoral bypass or an aortic thrombectomy.

CHRONIC LIMB ISCHAEMIA AND ARTERIAL RECONSTRUCTION

The management of patients with a chronically ischaemic limb requires a holistic approach, balancing the patient's potential functional capacity and comorbid conditions against the severity of the limb ischaemia and the level of symptoms. Possible salvage procedures, available autologous bypass conduit and the likelihood of success must also be considered, both before and after imaging. Although a patient with a chronic, non-critical ischaemia is often managed conservatively, there are some circumstances in which operative intervention is appropriate for incapacitating claudication.

Non-critical chronic limb ischaemia usually follows a relatively benign course, with low rates of limb loss or the necessity for salvage intervention. However, a proportion of patients will develop *critical limb ischaemia*. Pragmatically, critical limb ischaemia can be considered to be a limb threatened with loss of viability if left untreated, but it is defined by European Consensus criteria as a chronic situation (>2 weeks), resulting in rest pain and/or tissue loss in the form of ulceration or gangrenous digits. Typically, the ulcers appear over the bony prominences of the foot where skin is stretched or subject to pressure from footwear. The development of sensorimotor signs or calf



19.38 Embolectomy of a saddle embolus at the aortic bifurcation. (a) The catheter tip is above the embolus after introduction through the right femoral artery. (b) The residual clot is then removed via the left femoral artery. ⏎

tenderness (which implies muscle ischaemia) indicates impending limb loss, and intervention (either radiological or surgical) becomes necessary if amputation is to be avoided.

It is helpful to think of the lower limb blood supply as divided into three segments: the *aortoiliac* segment, the *femoropopliteal* segment and the crural pedal segment. Clinical examination will give a fairly good indication of the segments affected by occlusive disease. As a very general rule, it is unusual for a limb to become critically ischaemic if only one segment is involved. However, if the patient is diabetic, the foot may develop ulceration and web space sepsis in the presence of an arterial tree that is, to all intents and purposes, normal to the level of the upper calf. In addition, a patient may develop rest pain or tissue loss if relatively mild arterial disease is compounded by poor cardiac function or if collateral pathways have developed poorly.

Adequate imaging is essential before planning salvage procedures. A limb may be dramatically improved by simply dealing with the most diseased segment by radiological or surgical means. The operative strategies by anatomical segment are described below. The technical aspects of endovascular intervention are not discussed further, but these options should be considered, especially in aortoiliac disease, as either a definitive treatment or a method of improving inflow to allow a more distal bypass. Furthermore, there is evidence that femoropopliteal disease can be managed effectively by an endovascular procedure even in critical ischaemia.[38]

Before concentrating on individual operations, it is helpful to consider the principles governing the choice of procedure, which include the ‘conduit’, the ‘inflow’, the ‘outflow’ and the anatomical route taken to connect the recipient and donor vessels. Essentially, a graft will fail if the inflow is inadequate, if the outflow vessels are too diseased or if the conduit is inadequate in terms of quality, diameter or material. The most frequently used conduit with the best results for infra-inguinal bypass is the LSV (GSV). The vein must be more than 2.5 mm along its entire length with no thrombus and must be non-varicose. If the bypass is going only to the above-knee popliteal segment, a prosthetic material probably produces similar patency and limb salvage rates. However, for longer bypasses, multiple studies have shown that prosthetic material is inferior. The ipsilateral LSV is usually the preferred option, but other suitable superficial veins include the contralateral LSV, an SSV or an arm vein. A deep system vein, such as the femoral vein, can also be considered.

A graft can be routed in a way that mimics the vessel that it is replacing (an *anatomical bypass*) or in a way that does not (an *extra-anatomical bypass*). Examples of anatomical bypasses include femoropopliteal bypass, the aortobifemoral bypass and the iliofemoral bypass. Extra-anatomical bypasses include femorofemoral crossover grafts and axillofemoral grafts. The reasons for choosing a particular route include the choice of inflow and outflow vessels, the choice of anaesthetic technique and the patient’s general health. For example, an axillofemoral graft obviates the need to open the abdomen (for aortic cross-clamp), and a femorofemoral crossover graft can be performed under regional or even local anaesthesia.

AORTOILIAC DISEASE

Aortoiliac segment disease can frequently be managed by endovascular means and, as a result, the number of surgical procedures on this segment has fallen significantly over the past 20 years. However, anatomical and extra-anatomical bypasses are still necessary, normally in the context of long iliac system occlusions. The most commonly performed procedures are aortobifemoral grafts, axillofemoral grafts and femorofemoral crossover grafts. Resistance in a conduit is a function of the diameter and length of the bypass and outflow vessels. Conduit diameter is generally much larger than outflow vessels and thus is immaterial in terms of its contribution to the resistance of flow. Conduit length therefore is the determining factor in graft flow resistance. Longer grafts such as the axillofemoral graft has poor patency in the long term and should be considered only if the patient has chronic limb-threatening ischaemia and there is no option for a shorter bypass.

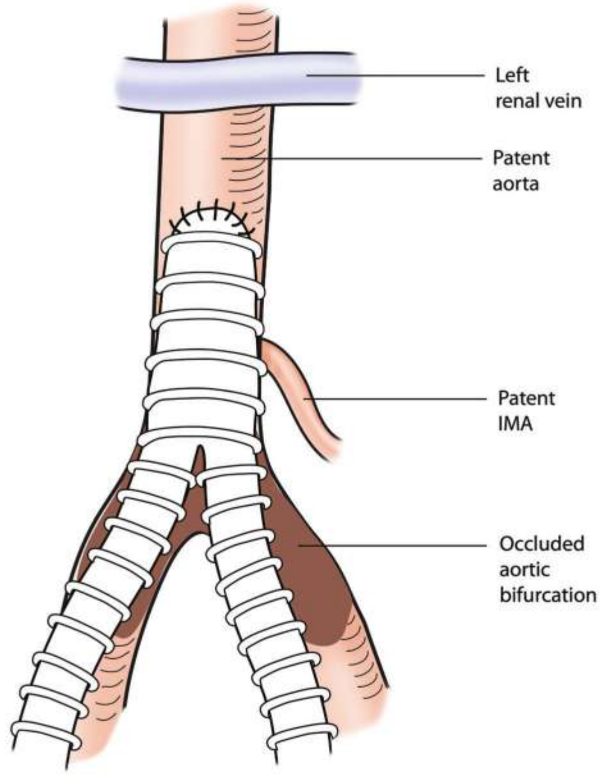
The groin dissection is described above. This is usually performed first to establish that the graft will have adequate outflow. The common inflow sources are the aorta, the axillary artery, the contralateral femoral system and, less commonly, the ipsilateral or contralateral iliac systems. Small modifications of the groin approach may be necessary according to the donor source, for example the direction of the skin incision and the orientation of the arteriotomy.

Aortobifemoral bypass

In occlusive disease, these grafts are performed in a fashion similar to that described above for aneurysms except that many surgeons prefer an end-to-side arrangement in the abdomen. This may be less haemodynamically favourable and more difficult to cover with peritoneum at the end, but maintains the collateral circulation to the pelvis and lower limb and provides some protection to the limb in the event of graft occlusion (Figure 19.39). This technique is particularly advantageous if it allows preservation of flow into a patent IMA. In many cases of aortic occlusion, the graft itself may be sited lower down the aorta than the angiogram first suggests. The top part of the occlusion often comprises fairly fresh thrombus that can be pulled out like a champagne cork using a Fogarty catheter. This is likely to be the case if the level of the occlusion extends up to the origins of the renal arteries and the aorta feels soft. The procedure for the preparation of the patient for bypass is described in Figure 19.40.

Axillobifemoral bypass

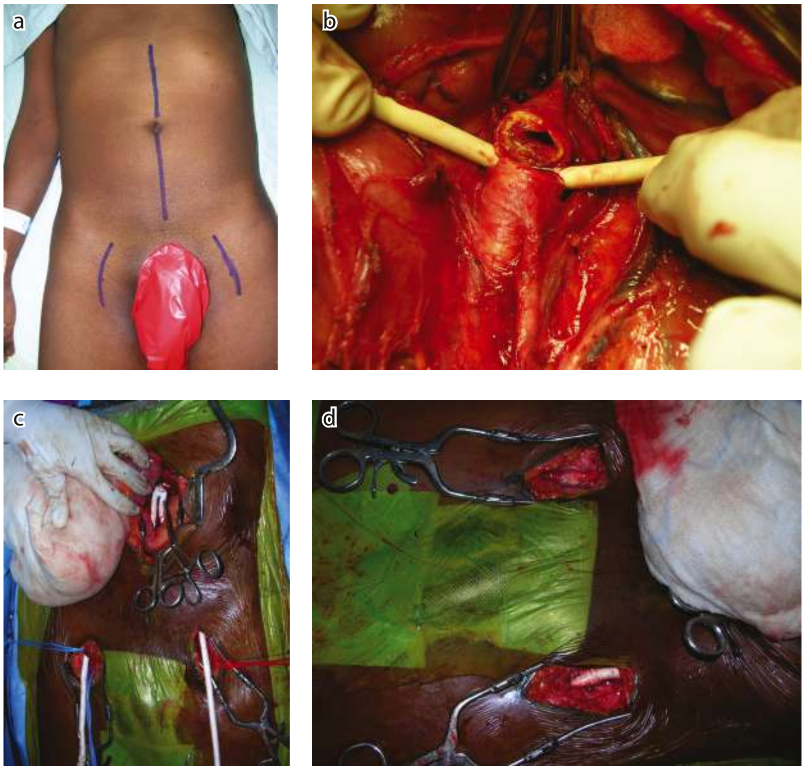
The advantage of the axillobifemoral bypass relates to the level of surgical insult to which the patient is subjected. No major muscle groups are incised, the abdomen is not opened and the aorta is not clamped. Axillofemoral grafts also play a role when there is a need to avoid a site of infection in the abdomen.



19.39 An end-to-side anastomosis may be preferred in an aortobifemoral bypass for occlusive disease. The IMA can be preserved and, if patent, this maintains some antegrade flow to the pelvic organs. In the event of graft failure, the limbs may also be partially protected by collaterals. ⏎

Before surgery, it is wise to check that the donor artery is disease free. Measuring the blood pressure in both arms can be enough, but many prefer the reassurance of a duplex scan to confirm normal flow patterns.

Access is better with the arm in abduction. An approach to the axillary artery is illustrated in Figure 18.7. However, as only limited access is required for this procedure, a smaller transverse incision, extending from 1–2 cm below the central portion of the clavicle to a point just below the medial limit of the deltopectoral groove, will suffice (see Figure 19.35). Once through the skin, the pectoral fascia is encountered. This fascia and the underlying pectoralis major muscle are incised along the lines of the fibres and held open with a self-retaining retractor. Deep to this is the clavipectoral fascia, which is incised. In so doing, a free edge of the pectoralis minor is exposed. This muscle can be retracted, divided at this stage or divided later. The pulsation of the axillary artery can usually now be felt clearly. The artery and vein are closely related, with the artery running slightly superior and deep to the vein. Tributaries to the vein can be ligated and divided. The artery must be slung with great care, as this is a very soft vessel that can



19.40 (a) The marking of the skin incisions prior to starting. (b) The aorta transected and an intraluminal atheroma. (c) Proximal aortic anastomosis is done and a bifurcated graft is routed retroperitoneally into the groin. (d) The distal anastomosis into the bilateral femoral artery is complete. ⏎

easily be torn or whose branches can be avulsed. It may be advisable to ligate the minor branches, especially those arising posteriorly, to prevent back-bleeding when the vessel is opened. Passing a tape around the artery as soon as it is safe will allow application of some gentle traction, which will be helpful during the more distal dissection.

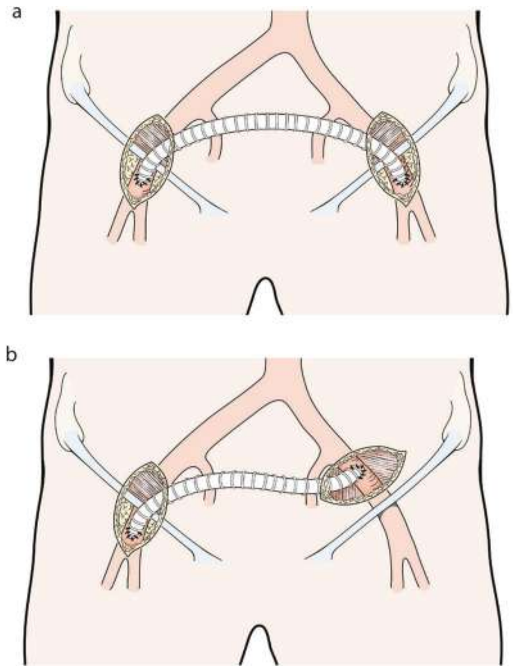
The tunnel should be created before heparin is administered. This is done by first running a finger deep to the pectoralis major and onto the chest wall. If the graft is only to one groin, then it is often possible to push the tunnel device from here all the way to the groin. The graft should run in the mid-axillary line before being directed medially to pass in a gentle curve, medial to the anterior superior iliac spine (see Figure 19.23b). If the groin is infected, the graft can be directed laterally for longer to allow passage through healthy subcutaneous tissue to the superficial femoral or mid-thigh profunda artery. If the graft is to go to both groins, an additional incision in the flank of the lower abdomen is often helpful. The surgeon has the choice here of using a commercially prepared bifurcated graft or suturing a crossover piece to pass from the groin, or higher, to the other side.

The additional incision allows the crossover portion to be placed carefully without kinking. Tunnelling in the subcutaneous plane of the abdominal wall carries a real risk of entering a body cavity or coming through the skin. It is important that the drapes are carefully placed at the start to allow as much view of the planned track as possible. Urinary catheterisation is advisable to reduce the chances of bladder damage.

The anastomoses at each end are performed in an end-to-side fashion, but it is important to ensure that there is enough length in the graft so that it is not tight, even at the extremes of movement of the very mobile shoulder joint. Arteriotomy of the axillary artery should be placed on the segment as close as possible to the chest wall. Lateral placement increases the risk of anastomosis avulsion and brachial plexus injury. The arteriotomy should be placed on the inferior portion of the artery to allow easy graft lie. The back wall of the artery is anastomosed first before the front wall.

Femorofemoral crossover grafts

This extra-anatomical bypass can be performed quickly under regional anaesthesia. The groin dissections are performed as described above. The graft is tunnelled subcutaneously just above the pubis (Figure 19.41a). Sometimes, it is helpful to arrange it so that each arteriotomy is slightly oblique so that the graft lies in a gentle curve. Again, care must be taken



19.41 Crossover grafts. (a) Femorofemoral. (b) Iliofemoral. ⏎

during tunnelling; the abdominal wall and even the bladder can be penetrated, especially in patients with previous abdominal surgery. Preoperative urinary catheterisation is advised. The graft can be placed subcutaneous or in the extraperitoneal retropubic space. The latter approach may be useful in an obese patient with a large abdominal apron with less risk of graft kink due to the weight of the abdominal apron.

Iliofemoral bypass

This is very similar to the femorofemoral graft, except that the common or external iliac artery is used as an alternative inflow (Figure 19.41b). The approach to the iliac arteries is by retroperitoneal dissection through a muscle-splitting incision. The external oblique aponeurosis is split first, up to the edge of the rectus sheath. The internal oblique and transversus muscle fibres are then split to reveal the peritoneum, which is swept up by blunt dissection in a superomedial direction towards the umbilicus. The use of a fixed retractor system such as Omni-Tract is helpful. Haemostasis in the retroperitoneal space is of importance to avoid troublesome postoperative haematomas. The retroperitoneal vessels are exposed and the arteries are easily dissected if this is an untouched field. The graft can be tunnelled in the retroperitoneal plane, similar to the aortobifemoral bypass, under the inguinal ligament.

Femoropopliteal segment disease

The patient with chronic, severe lower limb ischaemia affecting the femoropopliteal segment usually has a superficial femoral artery occlusion extending from its origin to the above-knee or, more commonly, the below-knee popliteal segment. Well-developed collateral channels from the profunda system may be sufficient to allow minimal, or indeed no, symptoms from a short femoropopliteal occlusion. However, disease progression either in the segment above or below or involving the common femoral or profunda vessels may result in severe claudication, progressing to critical limb ischaemia. Despite recent advances in therapeutic endovascular intervention, there remains a role for infra-inguinal salvage surgery, particularly in the context of complex lesions or long occlusions in any patient with a life expectancy estimated at greater than 2 years.[37]

As always, adequate imaging is key to the assessment of inflow and run-off. Ideally, there should be at least one complete vessel running out of the below-knee popliteal. In the face of probable amputation, some surgeons will still perform a bypass into a 'blind' popliteal segment, relying on a bed of collaterals or incomplete calf vessels to perfuse the leg. However, this option is rarely taken, as bypass to the distal vessels of the calf is effective and durable.

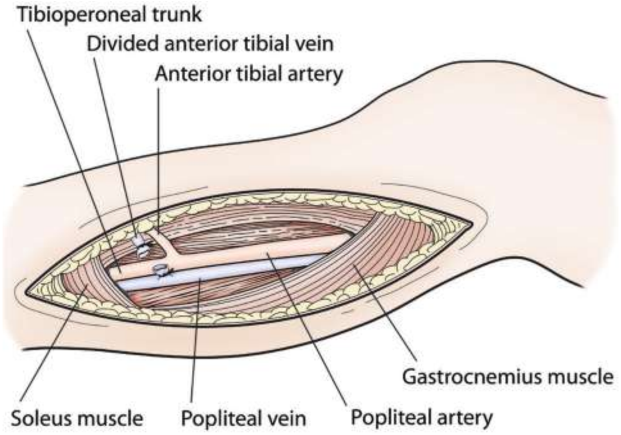
Femoropopliteal bypass

This bypass is the standard operation for femoropopliteal occlusive disease. The patient is positioned supine and the limb is prepared from the level of the umbilicus down to the ankle. If the foot can be placed in a clear bowel bag, this facilitates assessment of perfusion following revascularisation. The leg must be free enough to allow repositioning during the procedure. The recipient artery should be dissected first, to confirm that a bypass is possible. The common femoral artery is then isolated by a standard groin dissection, modified by an angled incision to allow additional access to the LSV. After both the inflow and the outflow vessels are exposed, the tunnel for the graft should be made prior to the administration of heparin.

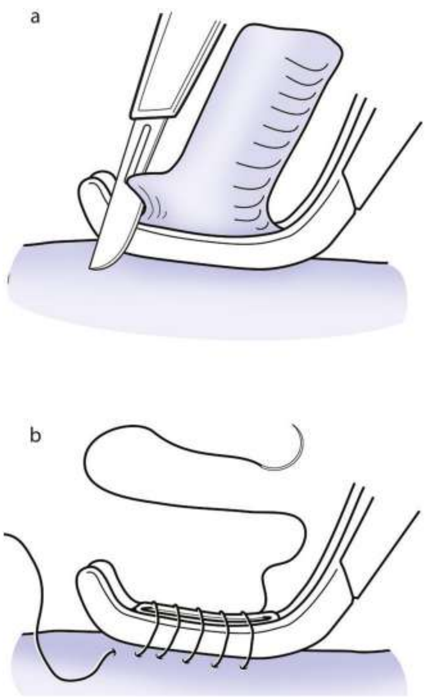
Exposure of the above-knee popliteal artery is achieved through a medial incision starting level with the upper part of the femoral condyle and extending proximally for 10 cm or so, a hand's breadth behind the patella. This is the surface marking of the LSV. The exploration proceeds through the groove between the vastus medialis muscle mass and the medial hamstrings (semitendinosus and semimembranosus). The sartorius and gracilis are retracted forwards with the vastus medialis. The muscles are held apart by a self-retaining retractor. The popliteal fossa at this level is often quite fatty and the artery is found on the underside of the femur, having just passed through the adductor hiatus. The femoral vein in this position is usually lateral (deep) or posterior (inferior) to the artery. The artery and vein are easily separated and, when mobilised, the popliteal artery can be brought to the surface. There are usually large genicular branches, which should be protected and preserved.

Exposure of the distal segment of the popliteal artery is also most commonly approached from the medial side. The skin incision is placed parallel and 1 cm posterior to the medial subcutaneous border of the tibia. The exposure is easier to perform if the knee is bent to 90° and the hip is flexed and abducted as much as the joint will allow. The LSV is marked prior to surgery using the portable ultrasound. It often lies directly under these markings, and there is frequently little subcutaneous fat to protect against damage at the time of skin incision. It must be freely mobilised and protected, and the medial head of the gastrocnemius is then retracted posteriorly, if necessary dividing some of the dense fascia connecting it to the tibia. The plane between the bone and muscle is opened to enter the distal popliteal fossa. Occasionally, the insertions of the tendons of the semitendinosus, semimembranosus and gracilis restrict access (see Figure 18.22). Some authorities advocate division of these structures, but space can usually be gained by full mobilisation and retraction of the tendons. The artery is deep to the vein, which may be single or a pair, and must be separated with some care, as venous bleeding at this stage can be difficult to control. If the popliteal artery is soft and suitable for the anastomosis, it may be enough to restrict the dissection to the true popliteal vessel. However, the proximal part of this arterial segment is often heavily diseased and it becomes necessary to place the arteriotomy more distally. Mobilising the region around the popliteal division requires division of the anterior tibial vein to allow access to the anterior tibial artery and tibioperoneal trunk (Figure 19.42). Clamping these vessels with a light bulldog clamp can be difficult, and it is necessary to double-loop and tighten the tapes, with or without the use of a vessel occluder.

Vein graft The LSV can be used either *in situ* or as a free reversed graft. In either case, the broad proximal segment of the LSV makes an ideal hood in terms of both size and shape for an anastomosis. For this reason, the LSV must be divided as close to the common femoral vein as is safe, using a Satinsky clamp to maximise the length of the vein graft (Figure 19.43). All tributaries of the LSV must be accurately ligated with a 1 mm stump length to avoid narrowing the vein. Care must be taken not to impinge on the vein by catching the adventitia in a knot and kinking the graft.



19.42 Medial approach to the below-knee segment of the popliteal artery. Note the divided anterior tibial vein, which has increased distal access and enabled the tibioperoneal trunk to be isolated. ⏎



19.43 A technique for dissecting the SFJ and maximising the length of the graft without compromising the lumen of the common femoral vein. (a) A clamp is applied at the junction and the vein is cut flush against it. (b) The common femoral vein is closed by suturing over the clamp. This suture is left loose and then the clamp is wriggled free, before returning with a second row of stitches to tie the suture to itself. ⏎

***In situ* grafts** This technique has the advantages of size-matching the vessels and reduced vein handling, and the potential for trauma is minimised. However, if the SFJ is significantly lower than the first soft portion of the common femoral artery, the LSV must be mobilised for some length down the thigh to allow a tension-free proximal anastomosis. Sometimes this is not possible at all. Disadvantages of *in situ* grafts include the need to deal with the valves, and the action of passing a valvulotome to destroy the valve cusps can damage the graft intima or even slice open the vein. Each tributary is also a potential fistula.

After completing the proximal anastomosis, the femoral artery clamp can be released. This allows some flow down the vein graft as far as the first competent valve and also allows the profunda system to perfuse the limb. The valvulotome is then passed up from the distal end of the vein, through a small venotomy, before dividing the distal end of the vein, or up the lumen of the free end if the vein has already been divided. The valvulotomy device must be passed several times, rotating it through 90° each time. Care must be taken when passing the device to minimise intimal trauma. The valvulotome can also tear the vein and disrupt the proximal anastomosis. The latter can be protected by the assistant pinching the graft closed just distal to the anastomosis.

There are several methods of identifying the tributaries, which must all be ligated. The whole length of the vein can be exposed for direct inspection. Alternatively, if an on-table angiogram is performed, a tape with radiopaque markers can identify the site of tributaries, allowing targeted incisions. A third option is to expose the vein through a series of short skip incisions. A handheld Doppler probe is then applied in turn to each segment of exposed vein, which is pinched closed just distal to the probe. If flow can be heard, there must be a patent more proximal tributary, which is then identified and ligated. This process is repeated until the distal end of the graft is pinched and no flow is detected.

Free reversed vein grafts The vein must first be harvested, reversed and tested. Preoperative duplex marking of the vein will indicate its course, distal diameter and sites of confluence. The vein can be harvested and tributaries can be ligated through a single long incision or through a series of interrupted or skip incisions. The latter approach takes longer, but may reduce wound complications. It is important not to cut obliquely onto the vein as undermining increases the risk of skin necrosis and other wound complications. The proximal end of the vein is divided at the SFJ, as described above, but the distal end of a free graft is best not divided until the arteriotomy sites at both ends have been decided. This may mean waiting until arteries are opened, as further vein length may be needed. The harvested vein is tested by gentle distension with heparinised saline: over-distension will damage the adventitia. Small holes, caused by the avulsion of tiny tributaries, may require repair with figure-of-eight stitches, but these must be placed so that they do not narrow the vein.

Prosthetic grafts A prosthetic graft may have to be used if there is no suitable vein. This is a satisfactory alternative if the graft does not have to be taken to below the knee (see Chapter 18).

Tunnelling

The graft can be tunnelled through a relatively anatomical pathway or placed superficially within the bed of the LSV. Some surgeons employ a combination of routes when bypassing onto the below-knee popliteal artery, leaving the vein superficial in the thigh but bringing it through the popliteal fossa from above to improve the angle and reduce the risk of graft kink by the hamstring tendons. The most important pitfall to avoid while tunnelling is a graft twist. One strategy is to release the clamp on completion of the proximal anastomosis and allow pulsatile flow through the graft. If the graft is twisted or kinked, it is often evident on inspection, but simply allowing forward flow through the graft may allow it to untwist if it has sufficient space to do so. If a hollow tunnel device is used, this has the advantage of providing space.

Anastomoses

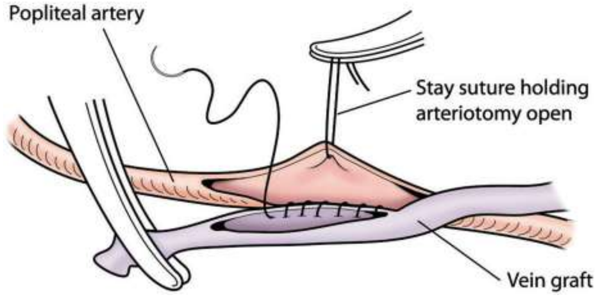
End-to-side anastomoses are usually performed and the techniques have been discussed in Chapter 18. The popliteal anastomosis can be difficult because of both restricted access and the size of the vessels. A clip on the redundant vein beyond the toe is helpful (Figure 19.44) and a parachute technique works well, allowing precise placement of each suture.

DISTAL BYPASS

The success of revascularisation surgery is dependent on adequate outflow. On occasion, the only outflow may be through a single crural vessel. Fortunately, these are relatively easy to access surgically.

Anterior tibial artery

The anterior tibial artery is most commonly exposed in the middle or distal third of the calf. The incision is made halfway between the lateral (subcutaneous) border of the tibia and the anterior border of the fibula. The tibialis anterior muscle is separated from the extensor hallucis longus and extensor digitorum longus muscles. The anterior tibial artery runs between these muscle groups on the interosseous membrane, and then on the tibia for a short distance before it



19.44 Popliteal anastomosis. A stay suture holds the artery open, making the suturing of the far side of the anastomosis easier. The vein graft is held by mosquito forceps, but this damaged portion of vein will be excised to shape the toe of the graft. ⏎

crosses the ankle into the foot underneath the superior extensor retinaculum. Graft routing options include:

- Subcutaneously, medial to lateral across the thigh, then past the knee on the lateral side
- Subcutaneously, down the medial aspect of the thigh and across the anterior aspect of the tibia
- Through the leg, by incising the interosseous membrane and creating a tunnel medial to lateral from the popliteal fossa to the anterior compartment

Posterior tibial artery

The posterior tibial artery is easily exposed along its distal third by a vertical incision starting 1 cm or less posterior to the medial subcutaneous border of the tibia, extended in a 'hockey stick' fashion under the medial malleolus if necessary. The posterior tibial artery is found quite superficially situated in a groove between the flexor hallucis longus and the flexor digitorum longus. Bypasses are ideally suited to an *in situ* LSV graft.

Peroneal artery

There are both medial and lateral approaches to the peroneal artery. With the lateral approach, a graft may be passed around the back of the fibula and, by separating the flexor hallucis longus muscle off the bone, a space can be created. More often, the lateral approach involves removing a segment of the fibula to expose the artery. Some authors describe a subperiosteal excision of the bone to allow it to be reimplanted at the end.

It is also possible to approach the peroneal artery from the medial side. This helps the harvesting and placement of the graft quite considerably. Taking an approach similar to that for the posterior tibial artery, the flexor hallucis longus is mobilised and the peroneal artery runs lateral to the tibial nerve in the groove between the fibular origin of the flexor hallucis longus and tibialis posterior.

Dorsalis pedis artery

It is possible to bypass onto the dorsalis pedis artery in patients with severe crural vessel disease (a pattern of disease most commonly seen in diabetic patients). The vessel can be visualised with a preoperative ultrasound and then exposed by making a vertical incision over the dorsum of the ankle and incising the extensor retinaculum lateral to the tendon of the extensor hallucis longus. The proximity of the LSV is useful for *in situ* reconstruction.

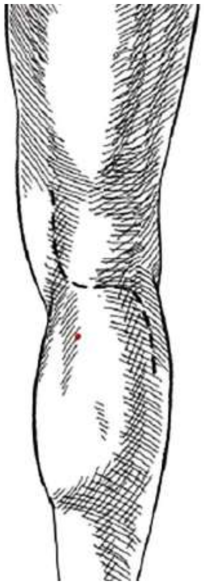
POPLITEAL ARTERY ANEURYSMS

The popliteal artery is the most common peripheral artery to be affected by aneurysmal disease, but nevertheless a popliteal aneurysm is relatively infrequent. The natural history remains largely uncertain. The principle concern is limb threat caused by either distal embolisation or acute thrombosis. All symptomatic popliteal aneurysms should be repaired, assuming that the patient is medically fit for intervention. Patients presenting as an emergency have an up to 50% chance of limb loss. Most vascular surgeons will consider surgical intervention for asymptomatic popliteal aneurysms that are greater than 3 cm, although for some surgeons the threshold for intervention is higher.[39]

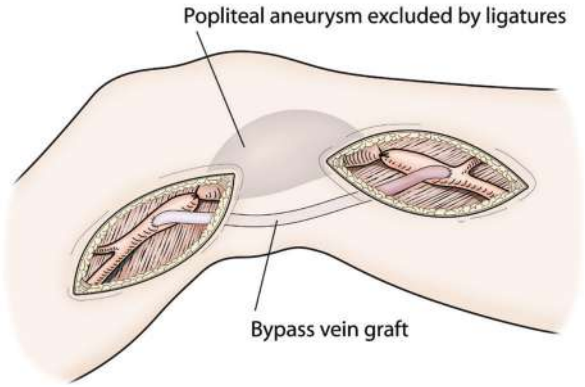
The aim of surgery, similar to that for aortic aneurysm, is to exclude the aneurysm from circulation and safeguard distal perfusion. A popliteal aneurysm can be approached posteriorly, through a lazy-S incision, with the patient positioned prone. This allows excellent exposure of the popliteal system in order to get above and below the aneurysm, but does limit access to the run-off vessels (Figure 19.45). It is also an unsuitable approach if the aneurysm extends above the adductor hiatus, as healthy artery will not be accessible. A short popliteal transverse skin crease incision is extended by a vertical extension up from its medial end and down from its lateral end.

A vertical incision is made in the deep fascia into the fat of the popliteal fossa. The SSV may have to be ligated for access, and care must be taken to protect the tibial nerves crossing the surgical field.

An alternative is a medial approach in which the above- and below-knee popliteal artery segments are approached as described above for a femoropopliteal bypass. The LSV is also easily harvested for the reconstruction without the necessity of turning the patient during the procedure. The two separate incisions, shown in Figure 19.46, can be converted to a single incision.



19.45 Lazy-S incision to access the popliteal artery in the prone position. The upper half is directed medially and the lower half is directed laterally. ⏎



19.46 Popliteal aneurysm. The popliteal artery has been approached from the medial aspect and ligated above and below the aneurysm. Distal perfusion is restored with a bypass graft. ⏎

A vein graft bypass is anastomosed end-to-side onto the popliteal artery, both above and below the aneurysm. Ligatures using non-absorbable sutures such as silk or polypropylene are then placed around the popliteal artery above and below the aneurysm to exclude it from the circulation (Figure 19.46).

BASICS OF ENDOVASCULAR SURGERY

Evolution of endovascular surgery

The origins of endovascular techniques can be traced back to the very human instinct to make things better and less invasive. This natural evolution to a less invasive future has left a profound transformative mark on present-day vascular surgery. A few seminal events in the development of endovascular surgery are as follows:

- Sven Seldinger's 1953 publication describing his ingenious and deceptively simple technique for catheter introduction after percutaneous needle puncture of the target vessel[40]
- Percutaneous transluminal angioplasty (PTA), which was first performed (successfully) in January 1964 by Charles Dotter
- Nicolai Volodos developing the use of stent grafts in the aorta in 1979
- Juan Parodi's first use of an aortic stent graft to treat an aortic aneurysm in 1990

Over the years, endovascular surgery has continued to evolve; these skills are an integral part of vascular patient care and will continue to be for the foreseeable future. On the basic level, guide wires and catheters are the universal instruments of success in endovascular work. Knowledge and ability must be achieved in several areas that are not necessarily inherent, including hand–eye coordination, predicting guide wire–lesion interactions, understanding the characteristics of various guide wire and catheter combinations, and learning when to quit. However, with adequate surgical skill as a backup, the option of bailout surgery always provides confidence.

Preparation for an endovascular intervention

Preparation for any operation is essential to start on the pathway to a successful intervention. A thorough knowledge of the patient's symptoms and comorbid conditions leads to an appropriate balance of how much intervention is required. For example, a patient with impaired renal function may develop irreversible worsening after the use of copious contrast. Similarly, a patient with calcified arteries may require the use of stents to keep the artery patent after a balloon angioplasty. A close study of the available imaging (duplex ultrasound/CT angiogram) prior to the case will provide valuable inputs to anatomical variations and judicious use of inventory.

Percutaneous access

Vascular specialists are now well versed in both open and percutaneous methods of access. The goal of arterial access is to provide safe and effective entry into the artery. Arterial access is of two types: antegrade, whereby the direction of access is the direction of blood flow, or retrograde, whereby the direction of access is against the flow of blood. The optimal puncture site choice should provide a low risk of complications and reasonable proximity to the site of intended intervention (Figure 19.47).

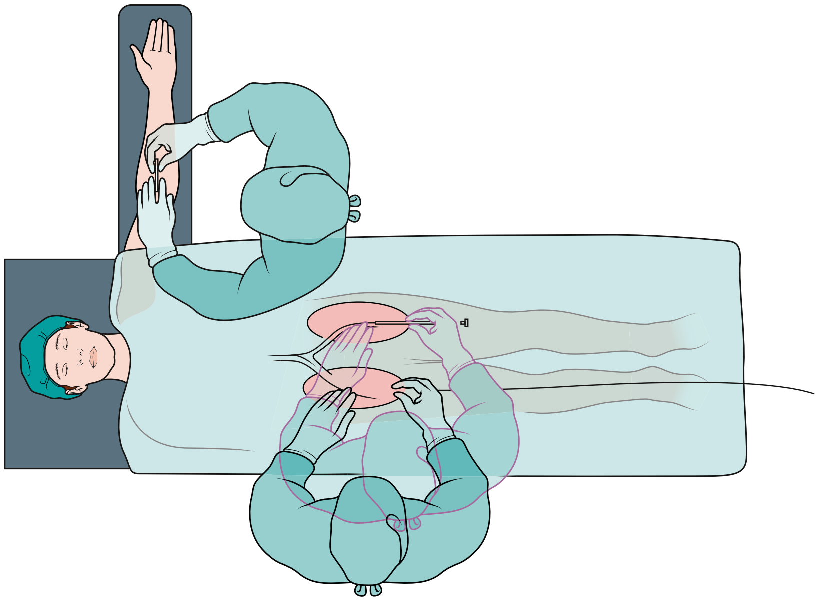
Common sites of access include the bilateral common femoral artery (for aortic, iliac or lower limb interventions), the brachial artery (for upper limb interventions), the radial artery (for cardiac interventions) and the tibial arteries (for retrograde lower limb interventions).

The most common complications of an endovascular intervention occur at the puncture site. The goal is a single perfect pass of the entry needle in every case. An ultrasound-guided puncture is a safe and effective way for quick vascular access. The Seldinger technique is the most common technique for establishing vascular access. The sequence of steps is as follows: needle puncture, the guide wire is threaded through the needle, the needle is removed, the flexible catheter is threaded over the guide wire and the guide wire is removed.[41]

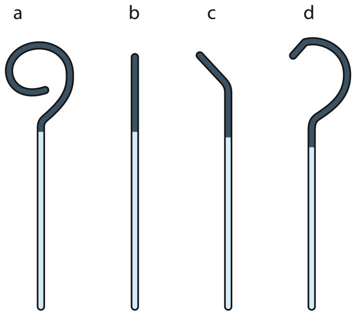
Choosing guide wires and catheters

Guide wires and catheters are the foundation of endovascular intervention. The role of the guide wire–catheter apparatus is similar to that of the arterial clamp. It provides control and permits access to the vasculature. There are several standardised platforms, and these are composed of different guide wire diameters. Sheaths and peripheral interventions are usually with 0.035 or 0.018 inch diameter guide wires; 0.014 inch guide wires are used in the smaller vessels such as the crural or pedal vasculature. Mastering the use of guide wires and feedback with the operators hands/fingers and understanding when to speed up, when to slow down, how firmly to grasp the wire, how hard to push, how to recognise tension in the guide wire, when to pull and when to push, when to try a different approach and when the chosen guide wire is not doing the job comes with practice.

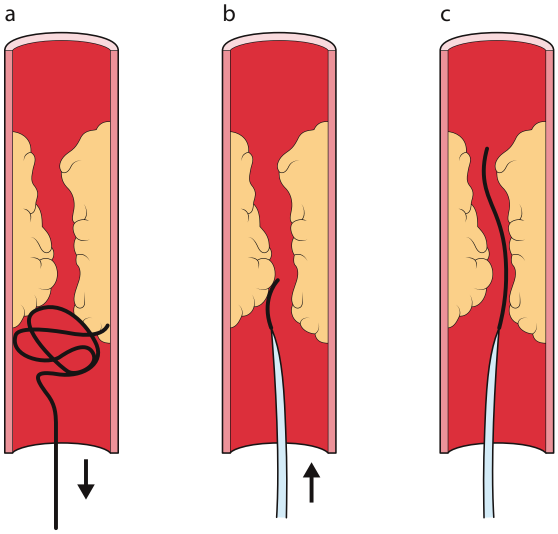
Angiographic catheters are constructed of polyethylene, polyurethane, nylon, Teflon or a combination of these materials. Based on the construction, the character of a catheter can change from soft/pliable to stiff/supportive. The diameter and length of the catheter must be the shortest possible to get the job done. 4–5 French catheters are commonly used for endovascular procedures. An exchange catheter is used for exchanging guide wires and may also be used for angiography. A flush catheter has an end hole with multiple side holes and is used for general angiography with high-flow contrast. Selective catheters have multiple head shapes and they are used to direct a guide wire into a specific location. Some selective catheters were designed with specific arteries in mind (e.g. carotid, visceral or crossing the aortic bifurcation) (Figure 19.48).



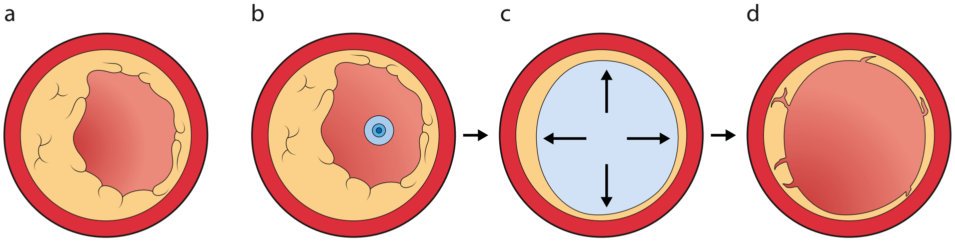
19.47 The operator works forehand whenever possible. In this example, the right-handed surgeon stands on the patient’s right side to puncture either femoral artery. Brachial puncture is also performed forehand. ⏎



19.48 Catheter head shape determines function: flush, exchange, simple-curve selective and complex-curve selective catheters. (a) Flush catheters are used for aortography. This flush catheter example is a pig tail catheter. (b) The straight catheter is used as an exchange catheter, to exchange guide wires into the artery. (c, d) Selective catheters have an end hole and a specially shaped tip. Selective catheters may have a simple curve, for directing a guide wire (c) or a complex curve, like this C2 Cobra (d). These catheters have specifically designed shapes and are used to enter aortic side branches such as carotid or renal arteries. ⏎



19.49 (a) A guide wire without support will buckle. (b) A straight catheter is used to support the guide wire while the guide wire gently probes the lesion. (c) Crossing the lesion with the guide wire, the catheter can be advanced over the wire and can also be used to confirm the crossing with angiography. ⏎



19.50 Balloon dilatation causes plaque fracture. (a) A cross-sectional view of an atherosclerotic lesion. (b) A balloon is placed in the lesion. (c) The radial force generated by dilatation is applied to the lesion. (d) Plaque fracture causes dissection. ⏎

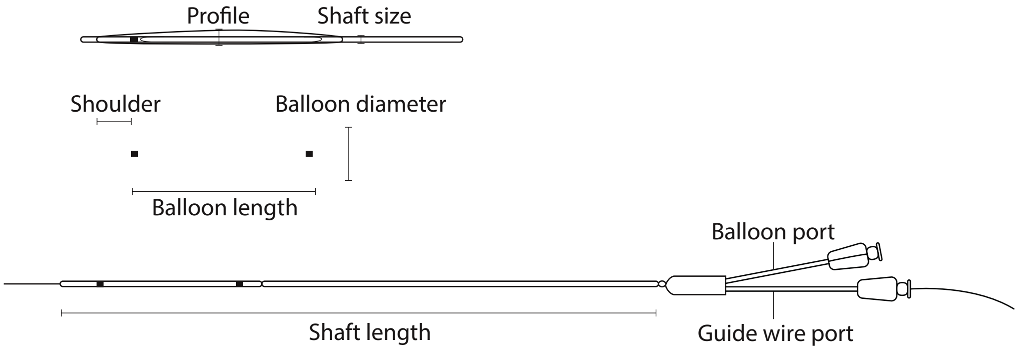
CROSSING A LESION

A lesion can be described as either a 'stenosis' or an 'occlusion'. Stenotic lesions have preserved lumen with reduction in calibre, while an occlusive lesion has no lumen. The lesion must be visualised with angiography before one attempts to cross it. The guide wire is selected on the basis of the lesion's appearance. Using the shortest and most direct route between the vessel entry site and the segment of interest offers the operator the most chance of a successful intervention. Interactions between guide wires and lesions are observed using fluoroscopy. Direct incremental advancement of a floppy-tip guide wire results in passage across long distances of normal or mildly diseased conduit artery. A catheter passed over the guide wire gives additional support to the guide wire shaft and secures the access site. The guide wire tip remains a few centimetres beyond the leading end of the catheter, and the guide wire is used to probe the lesion (Figure 19.49).

BALLOON ANGIOPLASTY AND STENTS

The radial force exerted by the angioplasty balloon causes plaque compression and fracture. This results in dissections within the plaque that lead to intimal remodelling. Experience with balloon angioplasty before the development of stents indicates that most of these dissections, depending on the arterial bed and direction of the dissection, usually heal without further treatment (Figure 19.50).

A coaxial (along the guide wire) balloon angioplasty catheter has two lumens. One lumen inflates the balloon and the other lumen is used for placement



19.51 The profile is the width of the folded balloon over the catheter. The shaft size depends on the size and type of the balloon. The shoulder is the distance from the radiopaque marker, where the balloon is filled out to its specified diameter, to the actual end of the balloon. The balloon diameter is the fully inflated diameter of the balloon. The length is the distance between the radiopaque markers. The shaft length provides a working distance between the operator and the angioplasty site. The balloon port is used to inflate the balloon, and the guide wire or distal port is used for passage over the guide wire. ⏎

over a guide wire (Figure 19.51). The balloon must not be inflated before reaching the target lesion, as it assumes a higher profile and becomes difficult to track over the wire. Balloon lengths can be between 2 and 20 cm. A balloon length that appropriately covers the lesion but does not extend into the normal vessel is ideal. The balloon catheter is advanced over the guide wire towards the entry site until the guide wire is available to be grasped on the other end of the catheter. The balloon catheter must not be inserted into the entry point unless manual guide wire control has been achieved. Radiopaque markers on the catheter at each end of the balloon are observed by using fluoroscopy to place the balloon in the correct location.

The pressure within an angioplasty balloon is universally measured in atmospheres (atm). An *atmosphere* is a unit of pressure that will support a column of mercury 760 mm high at sea level and at 0°C. All balloon catheters come rated with a nominal and burst pressure. Nominal pressure is the amount of pressure, in atmospheres, required to inflate the balloon to its labelled diameter. The rated burst pressure (RBP) is the pressure at which 99.9% of balloons can survive with 95% confidence. The failure of a balloon to maintain integrity at the RBP could result in device failure or vessel damage. Heparin must be administered at least 3 minutes prior to balloon inflation.

The balloon is inflated using an inflation device or hand injection (with smaller balloons) and is maintained for a minimum of 60 seconds after the pressure stabilises. After angioplasty, the balloon is completely deflated. The balloon is not moved until it is visualised using fluoroscopy to ensure complete deflation. The balloon is then removed, keeping the guide wire in place. There are different methods to assess the result of balloon angioplasty; a completion angiography is the best method. A residual stenosis of less than 30% is acceptable, even if the walls of the artery are irregular. If there is significant residual stenosis or in a flow-limiting dissection, the balloon angioplasty may be repeated for a longer duration (up to 3 minutes), failing which a stent may be required.

A stent is a minimally invasive way of relining the artery. The invention of stents has had a major impact on the development of endovascular surgery. Immediate treatment is required for the complications of balloon angioplasty (e.g. dissection and residual stenosis), and lesions (e.g. long occlusions or recalcitrant stenoses) that otherwise would have required open surgery may be treated with endovascular surgery. This provides an additional option for the treatment of patients who are at high risk for open surgery. Combining stents with graft material to create stent–grafts has allowed the treatment of aneurysm disease. However, each stent application has its own cost and complication risks due to foreign body implantation and stent–arterial wall interaction.

Stents are either balloon-expandable or self-expanding. Balloon-expandable stents are crimped onto a standard angioplasty balloon and deployed when the balloon is inflated, thus opposing the stent to the arterial wall. These stents perform best when placed in vessel locations that have the least mobility. A self-expanding stent deploys automatically to a predetermined diameter when unsheathed from its casing. They are more flexible but lack radial strength. The differences between the two types of stents are outlined in Table 19.2.

Self-expanding stents and balloon-expandable stents play complementary roles. Deciding on the type of stent to use may be somewhat subjective, but endovascular operators must become familiar with the use of each of these two general stent types.

Table 19.2 Specific features of and differences between balloon-expandable and self-expanding stents ⏎

Balloon-expandable stents	Self-expanding stents
Slotted-tube design	Wire mesh or slotted tube
High radial force	Low radial force (oversize for vessel)
Rigid	Flexible
Most functional at short lengths	Longer lengths are very functional
Premounted or mount onto balloon of choice	Delivery catheter with covering sheath
Some shortening with expansion	Variable shortening; some do not shorten
Steel or stainless steel	Nitinol or light metal alloy
Moderate radiopacity	Poor radiopacity (some have markers)

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20

Surgery of bone: Basic considerations and concepts

Hariharan T Dwarakanathan and Abinaya R Nadarajan

Despite the close relationship between orthopaedics and general surgery in the past, specialisation and rapid advances in both specialties have made it impossible to master both. Nevertheless, as a general surgeon, it is important to be knowledgeable about orthopaedic principles, which is why many surgical curricula include basic training in orthopaedics. Trauma surgery has further blurred the boundaries between the two specialties. Therefore, orthopaedic surgeons may not be required to be involved in certain surgical procedures involving bone, but both disciplines may be needed in some cases.

In resource-limited settings, such as war zones, conflict zones or remote areas, the general surgeon may have to function as an orthopaedic and a general surgeon. Traumatic bone injuries, and fractures, do not occur in isolation, and surgeons caring jointly for a patient with multiple injuries must understand the challenges in the other specialty. Interventions by vascular and orthopaedic surgeons may be needed simultaneously when a limb is severely fractured with a severed major artery. Other areas in which there are significant amounts of overlap are amputations and bone tumours. Resection of bone sarcomas may involve orthopaedic implants or local flaps.

For these reasons, and the fact that many isolated general surgeons may need to provide basic orthopaedic care, this chapter discusses some of the basic techniques, the principles of bone healing, osteomyelitis treatment and bone cancer treatment. This chapter is not intended to serve as a comprehensive reference for the specialist orthopaedic surgeon. Rather, it is designed to provide the general surgeon – who may be required to undertake orthopaedic procedures as part of a broader surgical practice – with the essential principles and techniques necessary for safe and effective management.

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STERILITY AND INFECTION IN BONE

Surgical site infections (SSIs) are associated with higher costs and inferior patient outcomes. SSI risk can also vary between surgical procedures and wound classifications. With regard to surgical wound categories, most orthopaedic elective procedures are considered clean wounds and should present the lowest risk of infection. However, some may be clean-contaminated surgical procedures, such as open fractures, and are at higher risk of SSI.

PREPARATION FOR SURGERY

Educating patients about personal hygiene before surgery is essential. Before surgery, patients should take a bath to remove particulates and grease. Methicillin-resistant *Staphylococcus aureus* (MRSA) colonisation can be checked by swabbing the nose and perineum before surgery. Individual practices may differ depending on hospital infection-control protocols.

Preoperative skin preparation involves the use of antiseptic solutions to reduce microbial contamination on the skin. The most common antiseptics are chlorhexidine and povidone-iodine. Alcoholic skin preparation solutions are more effective than aqueous skin preparation solutions. To minimise infection risk, hair removal should be carried out prior to surgery with clippers or epilator creams instead of razors.

THEATRE ETIQUETTE

The importance of maintaining a sterile environment cannot be overstated in the fight against SSIs. Infection prevention is paramount, especially when implants are used. To do this, the entire theatre team must be educated on the use of sterile instruments, gloves, gowns and drapes. Operating rooms must be properly prepared, and strict aseptic techniques must be followed.

Most orthopaedic operations in which implants are used require a laminar air flow theatre. Laminar air flow in theatres has been found to reduce the risk of prosthetic joint infections. To achieve laminar flow, there must be a continuous flow of highly filtered ultraclean air of <10 colony-forming units (CFU)/m^3 of bacteria. Once the contaminants are removed, the air is returned to the theatre, creating up to 300 air changes per hour. Operating room traffic should be kept to a minimum, and the number of personnel should be restricted. Keeping the operating area sterile begins with meticulous preparation and draping of the patient. It is important to follow a site-specific draping method by using appropriate adhesive drapes/clips and securing the drape with a sterile stockinette, if necessary, to isolate the surgical fields.

INFECTION IN BONE

Healthy bones are naturally resistant to infection. However, when exposed to bacteria due to high-velocity trauma, ischaemia or foreign bodies, they become vulnerable, as microorganisms can bind to damaged bone sites. Additionally, bacterial seeding of bone can occur haematogenously, spreading from distant infections. Among the most common orthopaedic infections surgeons encounter are:

- Septic arthritis
- Acute or chronic osteomyelitis
- Prosthetic or implant-associated infections

SEPTIC ARTHRITIS

Inflammation of the joints caused by infectious pathogens such as bacteria, fungi, mycobacteria, viruses or other pathogens is known as septic arthritis. It is usually monoarticular, but polyarticular septic arthritis affecting many joints is also possible. Patients typically present with a constellation of signs and symptoms, including joint pain, tenderness to palpation, swelling, erythema, warmth and painful or a limited range of motion.

Septic arthritis is diagnosed by examining the synovial fluid from the affected joint (culture, Gram stain, crystal analysis, white blood cell [WBC] counts with differential). The leucocyte esterase strip test is an invaluable bedside test. A high WBC count (>50,000) and neutrophil predominance (>90%) in synovial fluid indicates bacterial infection.

The most likely pathogens should be considered when choosing antibiotics, and they should be targeted based on microbiological results. Erythrocyte sedimentation rate (ESR) and C-reactive protein (CRP) are indicative of a diagnosis, but not conclusive. However, they improve sensitivity and specificity when combined.

When choosing antibiotics, microbiological results should be considered and the most likely pathogens targeted. The most common bacterial pathogen is *Staphylococcus aureus.* Specific age groups and medical conditions are associated with some aetiological agents. In children under the age of 2 or 3 years, *Kingella kingae* is the most common Gram-negative bacterial pathogen. Neonates are susceptible to group B streptococcus, *Staphylococcus aureus, Neisseria gonorrhoeae* and Gram-negative bacilli. Sexually active adolescents are at risk of *Neisseria gonorrhoeae* infection. Sickle cell disease is associated with *Salmonella* species infection. A patient on prolonged antibiotic therapy is at risk of fungal infections. *Pseudomonas aeruginosa* is associated with joint infections from puncture wounds and injection drug abuse. Fungal and mycobacterial organisms can present insidiously and are harder to diagnose – it is critical to treat these before joint cartilage is destroyed.

An arthrocentesis is the process of aspirating synovial fluid from the joint cavity. This test plays a crucial role in diagnosing septic arthritis. In most cases, it is still performed blindly using anatomical landmarks. This may sometimes lead to negative joint aspiration. The main advantage of ultrasound-guided arthrocentesis is the ability to see the effusion directly. The clinician can perform arthrocentesis with greater accuracy, and fewer attempts, by visualising the effusion and using in-plane or out-of-plane needle techniques. Additionally, ultrasound-guided arthrocentesis can detect small effusions that are not detectable using a landmark-based technique.

While arthrocentesis is considered a minor surgical procedure, it can cause injury to neurovascular structures or damage to chondral structures. A strict aseptic technique should be maintained when aspirating any joint to avoid infection. An understanding of the anatomy of the joint to be aspirated helps avoid complications. One should ensure that an adequate sample is collected.

Septic arthritis is treated with antimicrobial therapy and/or arthroscopic/open drainage of joint fluid. After joint aspiration and culture have been obtained, intravenous antimicrobial therapy should be initiated immediately. Empiric intravenous antibiotic coverage includes anti-staphylococcal drugs. Additional antibiotics should be prescribed based on age, risk factors and Gram stain results. When community and institutional data indicate that MRSA is suspected, intravenous vancomycin should be administered. For additional Gram-negative coverage, a third-generation cephalosporin such as ceftriaxone, ceftazidime or cefotaxime should be added if the Gram stain is negative or there is clinical suspicion. To determine when and how to drain joint fluid, an orthopaedic surgeon must be involved at an early stage.

OSTEOMYELITIS

The term osteomyelitis refers to a bone infection. Osteomyelitis is an acute or chronic inflammation of the bones, and their structures, resulting from infection with bacteria, fungi or mycobacteria. Bone can get infected via the haematogenous route of infection through seeding from a distant source of infection, contiguous spread from surrounding tissue and joints, or direct inoculation of bone from trauma or surgery. The site of infection may be determined by localised signs and symptoms.

Trauma, scar tissue, poor circulation, diminished sensibility, chronic bone or joint disease, foreign bodies, implants and poor circulation are all local factors that increase the host's susceptibility to infection. Malnutrition, general illness, debility, diabetes, rheumatoid disease, corticosteroid administration and any form of immunosuppression are systemic factors that contribute to infection, as are malnutrition, general illness and disability.

Until antibiotics were introduced, osteomyelitis was mainly treated surgically with extensive debridement, saucerisation and wound packing, followed by secondary intention healing resulting in high mortality from sepsis. Since antibiotics became available, mortality rates from osteomyelitis have significantly decreased. Due to polymicrobial and multidrug-resistant organisms, surgery has again become the mainstay of the treatment of orthopaedic infections.

The effective treatment of osteomyelitis requires collaboration among a variety of healthcare providers. Surgical containment of the infection and prolonged antibiotic therapy are the two main components of therapy. It is often necessary to surgically remove all diseased bone, and granulation tissue, because antibiotics do not penetrate infected fluid collections such as abscesses or necrotic bone.

Biofilms are protective coatings formed by some bacteria around themselves and underlying surfaces. This characteristic of some bacteria being able to adhere to the bone and implants – following which they express phenotypic resistance to antibiotic therapy – and to survive intracellularly may explain the persistence of bone infections and high treatment failure rates.

Acute osteomyelitis

This is defined as acute pyogenic infection of bone surface, or marrow, by infecting organisms. Children are most likely to suffer from acute haematogenous osteomyelitis. Adults are most likely to be affected when their resistance to infection has been reduced.

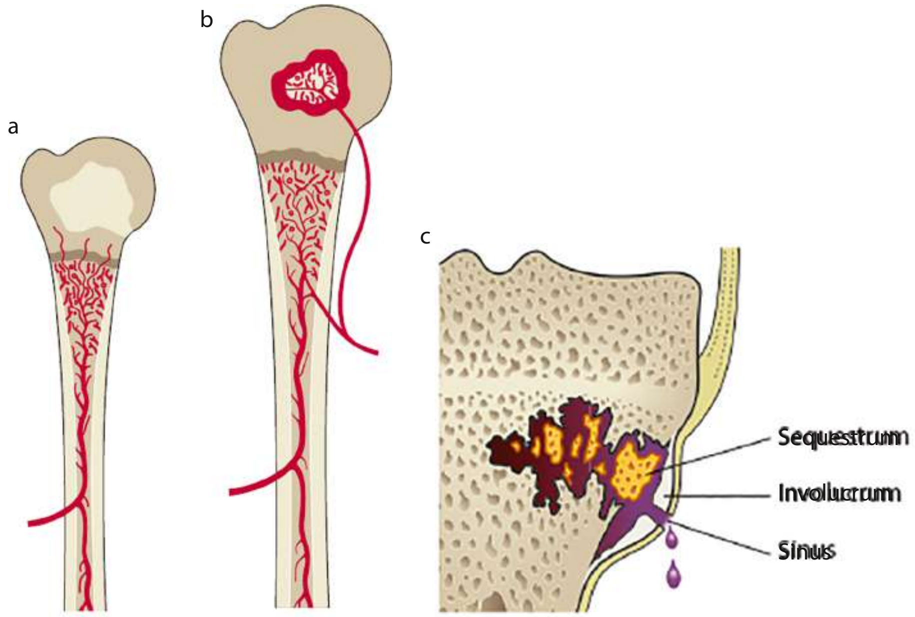
Acute osteomyelitis is caused primarily by *Staphylococcus aureus*, but less often by other Gram-positive cocci, such as beta-haemolytic streptococci, which cause chronic skin infections, and group B streptococci (especially in newborns) or alpha-haemolytic diplococcus. The Gram-negative *Haemophilus influenzae* used to be a common pathogen among children between the ages of 1 and 4, but vaccination has significantly reduced the number of cases.

Children usually develop the infection in the proximal tibia or distal or proximal ends of the femur's vascular metaphysis. The preference for this site may be explained by the peculiar arrangement of blood vessels in this area: non-anastomosing terminal branches of the nutrient artery wind back into hairpin loops before entering the sinusoidal vein network. Bacterial colonisation is believed to be favoured by relative vascular stasis and a low oxygen pressure. A hypertrophic zone of the metaphysis may have fine vessels that allow bacteria to pass through and adhere to type 1 collagen more easily. It is possible for infection to reach the epiphysis in infants, who still have anastomoses between their metaphysis and epiphyses (Figure 20.1).

Increased intraosseous pressure causes intense pain and blood flow obstruction. A combination of phagocytic activity and the accumulation of cytokines, prostaglandins and bacterial enzymes threatens bone tissue even at an early stage. The pus forms within the bone and forms a subperiosteal abscess by the second or third day. Due to the relatively loose attachment of the periosteum in children, this is more obvious than in adults. Subperiosteal abscesses can cause pus to spread along the shaft and burst into surrounding soft tissue. Where the metaphysis is intracapsular, the pus may leak into the joint through the developing metaphysis. As bone continues to be destroyed, it may leave behind a nidus inaccessible for destruction or repair called a *sequestrum*. The new bone, involucrum, starts forming on viable surfaces in the bone and from the deep layers of the stripped periosteum. In the event of a persistent infection, pus and tiny sequestered spicules of bone may escape through perforations (cloacae) in the bone.

Thus, untreated osteomyelitis rapidly progresses to ischaemic necrosis of bone. A state of chronic osteomyelitis is then established, which can last a lifetime. In the child, damage to the adjacent growth plate may cause long-term sequelae. Acute osteomyelitis in children is characterised by pain, fever, failure to gain weight, an elevated WBC count, an elevated ESR and an elevated CRP.

Plain radiographs show no abnormalities during the first week after symptoms begin. Displacement of fat planes is a sign of soft tissue swelling, but it



20.1 The aetiopathogenesis of acute osteomyelitis showing the arrangement of blood vessels that predispose to acute osteomyelitis in children. (a) Metaphyseal capillaries (hairpin-loop arrangement). (b) Infection spreading to the epiphysis (in infants only). (c) Sequestrum, involucrum and sinus formation (chronic stage); sequestrum is dead, necrotic bone (avascular due to infection); involucrum is new bone formed by elevated periosteum (the body's attempt to wall off infection); the sinus tract is a draining pathway for pus through soft tissues. (From Blom et al.[5], with permission.) ⏎

could also indicate a haematoma or infection. The periosteal new bone may form an extracortical outline by the second week, a classic X-ray sign of early pyogenic osteomyelitis, but treatment should not be delayed while waiting for X-ray signs. A subperiosteal collection of fluid may be detected by ultrasound, but it cannot differentiate a haematoma from pus. Technetium Tc-99m hydroxydiphosphonate (99mTc-HDP) radio scintigraphy reveals increased activity in both the perfusion and the bone phases. Despite its high sensitivity, it has relatively low specificity, and other inflammatory lesions can show similar changes. Hybrid single-photon emission computed tomography/computed tomography (SPECT/CT), if available, can be an alternative to radionuclide scanning. SPECT/CT improves the localisation of infection and defines its extent more accurately.

If antibiotics are given early (within the first 48 hours after the onset of symptoms), drainage is often unnecessary. Surgical drainage consists of an incision down to bone at the level of maximum tenderness and swelling. Any subperiosteal abscess is evacuated. If there is no obvious abscess, it is reasonable to drill a few holes into the cortex of the metaphysis to allow the release of an intraosseous abscess. Pus should be saved to allow identification of the infecting organism. The skin incision may be closed over a vacuum drain, but the wound should remain visible for inspection. A plaster cast should be applied if there is any danger of a pathological fracture developing, but a window must be cut for wound inspection. The situation should also be monitored by radiological imaging and inflammatory markers. When the signs of infection subside, the child is encouraged to move and is allowed to walk with crutches. It usually takes 3–4 weeks for a patient to be able to fully weight-bear on a limb.

Chronic osteomyelitis

Untreated acute haematogenous osteomyelitis will eventually develop into a chronic bone infection with intermittent flare-ups and apparent quiescence. Scar tissue with dead, and dying, bone around the infection compromises the host's defences. In addition, bacteria covered in a polysaccharide slime (glycocalyx) can adhere to inert surfaces such as bone sequestrum and metal implants, where they multiply and colonise and lead to antimicrobial resistance. Infection of the bone is accompanied by devitalisation, either in a discrete area around the infection or more diffusely. The patient may present with pyrexia, redness, or tenderness or discharging sinuses.

X-ray examination will usually show bone resorption either as a patchy loss of density or sometimes as a thickening and sclerosis of the surrounding bone. Despite its sensitivity, radioisotope scintigraphy is not very specific. A 99mTc-HDP scan reveals increased activity in both the perfusion and the bone phases. The use of 67Ga-citrate or 111In-labelled leucocytes is said to be more specific for osteomyelitis. Both computed tomography (CT) and magnetic resonance imaging (MRI) will show the extent of bone destruction and reactive oedema, as well as hidden abscesses. When complex cases are involved, SPECT/CT may offer advantages in terms of sensitivity and local definition.

The histology reveals chronic inflammatory cell infiltration around regions of acellular bone or microscopic sequestrum. It is possible for CRP, ESR and WBC levels to increase during acute episodes. In about 20% of cases of overt infection, bacterial cultures are negative. More sophisticated molecular techniques have been developed in recent years, based on the amplification of bacteria's DNA or RNA fragments using polymerase chain reaction (PCR). It is useful to stage chronic osteomyelitis to determine the risk–benefit ratio and to predict the outcome of treatment. In 2003, Cierny and colleagues popularised a system based on both local pathological anatomy and host background (Table 20.1).

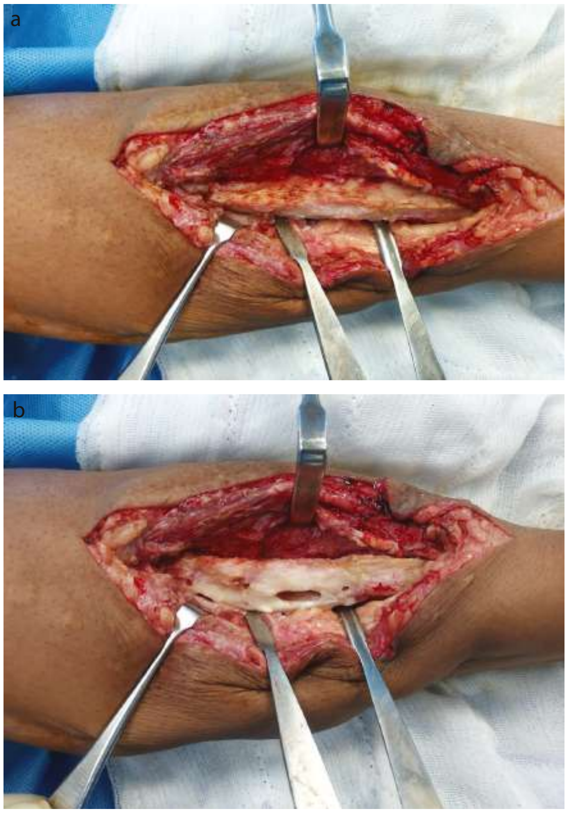
Chronic osteomyelitis cannot be cured with antibiotics alone. Despite this, bactericidal drugs are crucial for suppressing infection and preventing its spread to healthy tissues and controlling acute flares. The organisms cultured from discharged sinuses should be tested repeatedly for antibiotic sensitivity because they often change characteristics over time and become resistant to treatment. Treatment is often multidisciplinary and involves orthopaedic surgeons, plastic surgeons and microbiologists.

The management of chronic osteomyelitis involves radical debridement (curettage, burring and excision of necrotic bone and unhealthy granulation tissue) to eliminate infection (Figure 20.2). Dead space

Table 20.1 Staging for adult chronic osteomyelitis ⏎

Type	Description
Anatomical type	
1	Medullary
2	Superficial
3	Localised
4	Diffuse
Host category	
A	Normal
B	Compromised by local or systemic conditions
C	Severely compromised by local and systemic conditions

Clinical stage = anatomical type + host category.



20.2 Chronic osteomyelitis of a forearm treated with curettage, burr and removal of unhealthy granulation tissue. The tissue defect, if massive, may need a local muscle or free flap. The wound is closed over a suction drain (preferably greater than 14 French in diameter) and with cement/antibiotic beads for local drug delivery. (a) Intraoperative exposure of the radius during sequestrectomy – adequate bone exposure for debridement with curettage and burr. (b) Post-debridement appearance after thorough curettage, burring and removal of unhealthy granulation tissue. ⏎

management is crucial, with options such as local muscle flaps or free flaps for large defects. Antibiotic therapy (culture-guided, systemic/long-term) is essential. In some cases, bone stabilisation (external fixation) may be required if structural integrity is compromised.

PERIPROSTHETIC JOINT INFECTIONS

A periprosthetic joint infection (PJI) is a prevalent and potentially chronic complication associated with joint replacement surgery. It is of significant clinical relevance to the patient, surgeon and healthcare system. In terms of clinical manifestations, there are three categories: early-onset PJI (within 3 months of surgery), usually caused by intraoperative contamination by relatively virulent microorganisms; delayed-onset PJI (3–12 months after surgery), caused by less virulent microorganisms, but with the same origin at surgery; and late-onset PJI (more than 12 months after surgery).

The microorganisms that cause PJI are most often *Staphylococcus aureus* and less frequently coagulase-negative *Staphylococcus*. Together, they account for more than half of all PJIs. Approximately 20–30% of infections are caused by streptococcus species, enterococcus species, aerobic Gram-negative bacteria and some anaerobic bacteria (e.g. *Propionibacterium acnes* in the shoulder). Polymicrobial infections account for 10–20%, while the remainder are culture-negative or infrequent microorganisms. Multiresistant microorganisms are becoming increasingly prevalent.

In most cases, the diagnosis is based on criteria set out by the Musculoskeletal Infection Society (MSIS) in 2018, which included major and minor criteria. Surgery options include debridement with prosthesis retention (particularly in early infections originating from haematogenic sources), one-stage arthroplasty exchange, two-stage arthroplasty exchange with or without antibiotic-loaded polymethylmethacrylate spacer, arthroplasty resection without reimplantation and even long-term antibiotic therapy alone as suppression therapy.

SURGERY OF BONE: BASIC SURGICAL TECHNIQUES

The skills required for surgery on bone are very different from other specialties. Instruments are required for facilitating surgery, assisting fracture reduction and creating osteosynthesis. An elevator, a lever and a retractor are special instruments used during the surgical approach. It is imperative to use self-retaining retractors, or soft tissue retractors, as much as possible to facilitate an effective approach and prevent surgical assistant fatigue. Hohmann retractors are indispensable and are used abundantly in orthopaedic surgery.

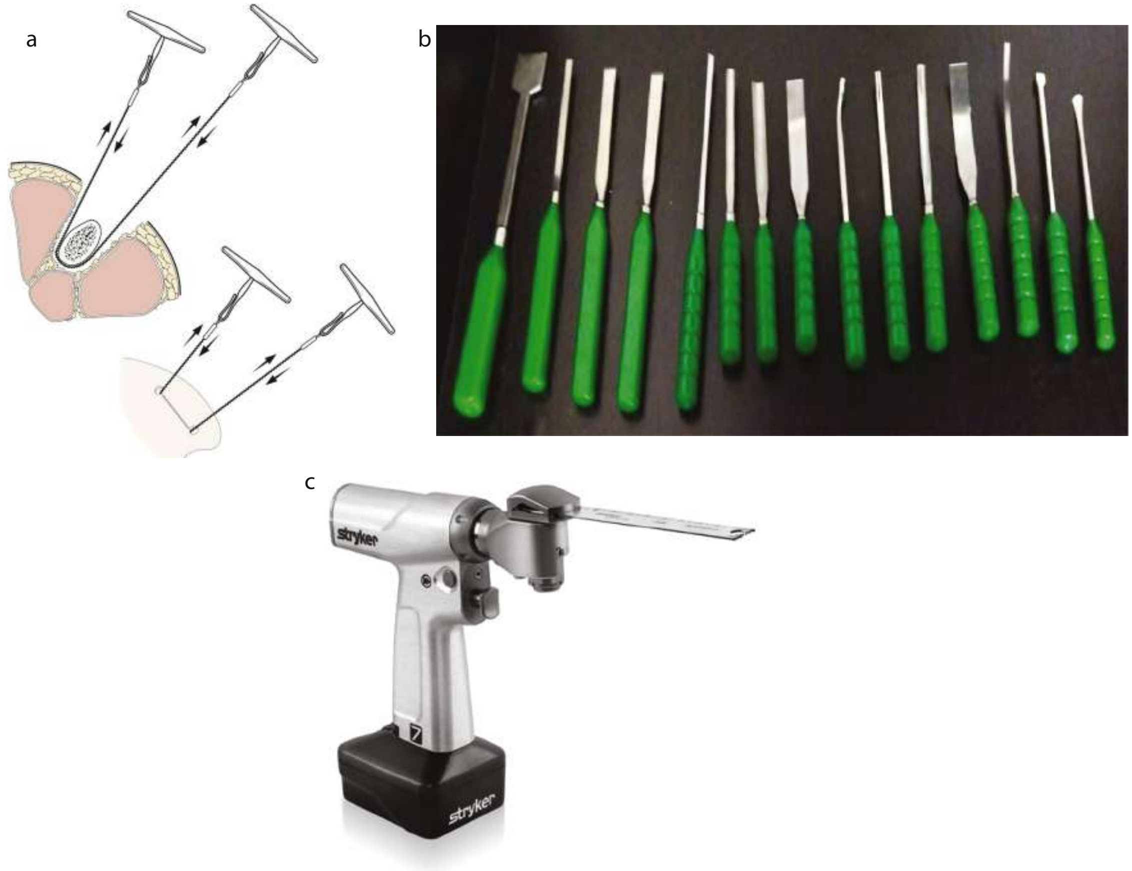
Meticulous preservation of bone blood supply is more important than perfect fracture reduction. Indirect methods ensure the fracture area remains covered by the surrounding soft tissue, but they are technically demanding. Fracture surgery has increasingly become soft tissue surgery rather than bone surgery with an emphasis on protecting the endosteal and periosteal blood supply. The repeated use of bone clamps, reduction tools and implants may devitalise the fragments, having disastrous effects on the healing process. Most orthopaedic operations require the use of power tools to cut and drill bones. These tools are autoclavable and have evolved over the years to the present-day sleek and ergonomic versions. There are certain instruments that overlap significantly between general and orthopaedic surgeons, such as the bone nibbler, bone rasp osteotomes and Gigli saw (Figure 20.3a, b). They enable precise bone resection, debridement and reconstruction. Today's powered instruments improve efficiency while maintaining sterility (Figure 20.3c).

An external or internal fixation device can be used to stabilise and promote the healing of fractures. Intramedullary nails and plates are the most commonly used internal fixation devices. It is necessary to have a set of instruments to perform each of these procedures successfully. For example, the typical instrumentation for plate osteosynthesis includes a drill with coupling devices for drill bits and K-wires, drill bits and taps sized appropriately, sleeves for drill bits and taps, depth gauges, double drill guides, plate-holding forceps, bending irons, aluminium templates and screwdrivers. Equipment varies depending on implant size and plate fixation method. Depending on the situation, the same plate can be used in neutralisation mode, bridging mode or compression mode. Most implants are currently site-specific and are designed to fit anatomically to the contours of the bone for which they are intended. When using plates and nails, the operative technique must be followed for that specific implant.

BONE HEALING IN FRACTURES AND ELECTIVE ORTHOPAEDIC SURGERY

There are four Arbeitsgemeinschaft für Osteosynthesefragen (AO) principles of fracture fixation:

1. Fracture reduction to restore anatomical relationships
2. Fracture fixation providing absolute or relative stability as the type of fracture, patient and injury requires
3. Preservation of blood supply to soft tissues and bone



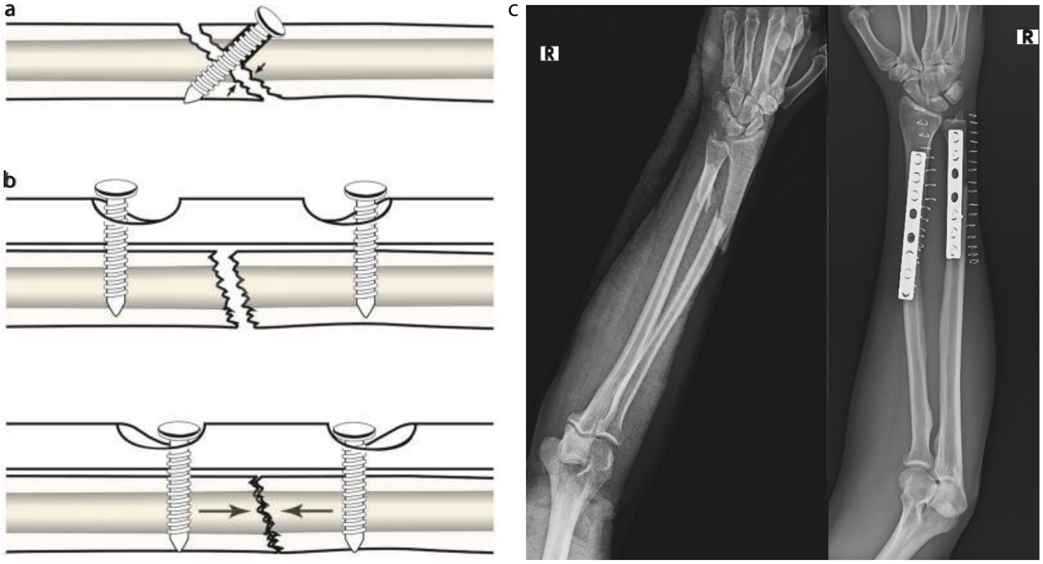
20.3 (a) Access to bone with a classical saw may be obstructed by soft tissue. A Gigli saw overcomes this problem. It can also be used to divide a flat bone (e.g. ilium or cranium) between two drill holes. (b) Various osteotomes used in orthopaedic surgery. (c) Modern electric oscillating saws are now preferred in most situations. (Stryker Instruments, Kalamazoo, MI, USA.) ⏎

4. Early and safe mobilisation of the injured part and the patient.

The process of bone healing involves rebuilding bone after a fracture. Basically, there are two types of bone healing: primary and secondary. When the fracture site is perfectly reduced, aligned and fixed under compression, primary (direct) healing occurs. When these conditions are met, bone can heal through direct remodelling of lamellar bone and Haversian canals. Cutting cones are formed at the ends of the osteons closest to the fracture. By crossing the fracture line, these cones generate longitudinal cavities (via osteoclasts) that are filled by bone matrix (via osteoblasts). This results in the generation of bony union and restoration of Haversian systems that allow for blood supply to be restored. Compression plating techniques, like dynamic compression plates, enhance bone healing by actively reducing fracture gaps. Proper implant positioning, as seen in this forearm plate fixation, ensures rigid stabilisation and promotes primary bone union (Figure 20.4).

While primary bone healing can be achieved by open reduction and internal fixation under compression, secondary (indirect) bone healing is more common. There are four stages of secondary healing, including intramembranous and endochondral ossifications. First, a haematoma forms as part of the acute inflammatory response. Haematomas coagulate to form a temporary scaffold that promotes callus formation, triggering acute inflammatory markers such as tumour necrosis factor alpha (TNF-α), interleukin (IL)-1 and IL-6. They attract macrophages, monocytes and lymphocytes that remove necrotic tissue and secrete cytokines, such as vascular endothelial growth factor (VEGF), which promote healing and angiogenesis. This initial phase lasts approximately 5 days.

The second stage is the formation of the fibrocartilaginous network; mesenchymal stem cells are recruited and differentiated into fibroblasts, osteoblasts and chondroblasts. The formation of a collagen-rich fibrocartilaginous network (soft callus) at the fracture site initiates chondrogenesis. A layer of woven bone is deposited simultaneously. Typically, the stage begins on day 5 after the fracture and lasts for approximately 5 days. As the soft callus (cartilaginous



20.4 (a) Screw fixation across a fracture. The screw should cross the fracture at right angles. 'Overdrilling' of the proximal cortex results in compression of the fracture as the thread 'bites' in the distal cortex. (b) Internal fixation of a fracture with a plate must hold the bone ends in apposition. Additional compression of the fracture can be achieved by a variety of techniques. The simplest is a plate with obliquely bevelled oval screw holes. As the sloping shoulder of the screw is tightened against the plate, the small lateral movement compresses the fracture. (c) The X-rays show a plate fixation of the forearm that has been done using the same principles. ⏎

callus) undergoes endochondral ossification to form the hard callus (via chondroblasts and osteoblasts), the bony callus forms. It involves resorption of cartilaginous callus and deposition of woven bone subperiosteally. Finally, the bony callus is remodelled via osteoclasts and osteoblasts to form compact bone centrally and lamellar bone peripherally.

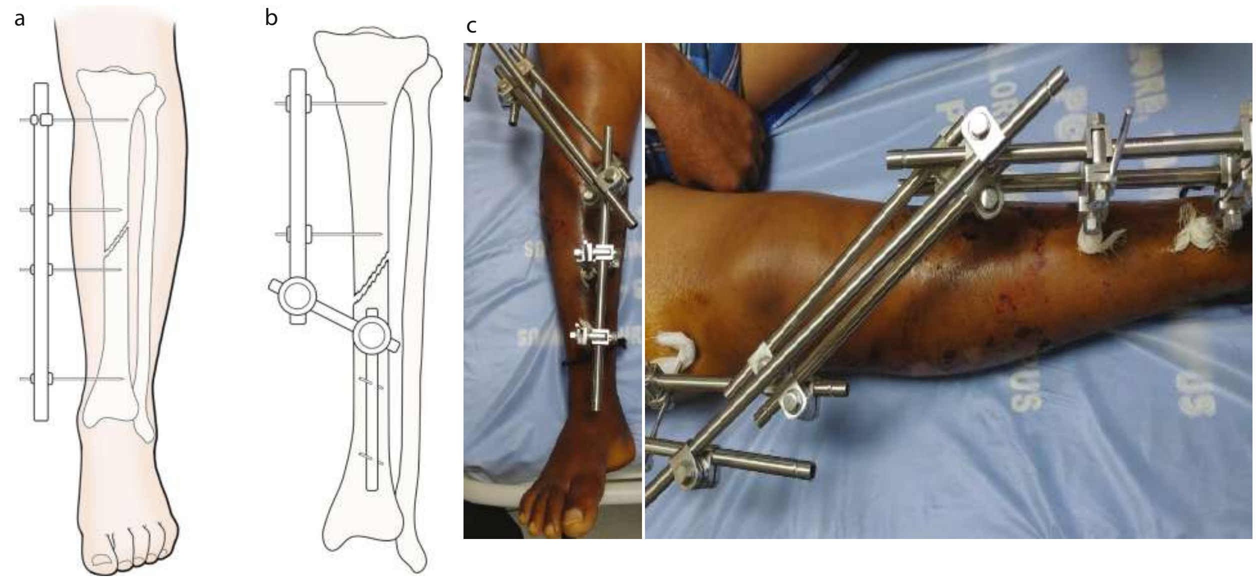
Malunion and non-union

Generally, a malunion describes a fracture that has healed in an unfavourable position, resulting in deformity or dysfunction. Malunions can be classified based on their location, for instance intra-articular, metaphyseal and diaphyseal. Furthermore, they can be defined as simple (one plane) or complex (multiple planes and translation) deformities. A painful and disabling articular incongruency that leads to progressive arthritic changes with instability should be treated with surgery, particularly in the lower extremities.

Based on the local situation, the function of the joint, the age of the patient and socioeconomic factors, secondary reconstruction, extra-articular correction osteotomy, arthrodesis or arthroplasty may be performed. There is no definite need to correct metaphyseal malunion if pain and functional disability are absent. It is particularly important to consider the long-term prognosis in such cases. In cases of malunion in the shaft, the main question is at what level a corrective osteotomy should be performed. Although the primary objective is to restore anatomy and function, the condition of the soft tissues and bones at the level of the deformity may pose a high-risk factor for a long-term complication.

Non-union occurs when a fracture has ceased to show any evidence of healing, as indicated by persistent fracture lines, sclerosis at the fracture ends, a gap and hypertrophic or absent callus. Unless there is bone loss, a non-union is usually said to have occurred between 6 and 8 months after the fracture. The main factors leading to non-union are usually disturbed vascularity and instability, although others, such as non-compliance and neuropathies, may also inhibit healing. Infection is also a cause of non-union. Diaphyseal non-unions are of two types: hypertrophic and atrophic non-unions. Hypertrophic non-union is frequently localised in the lower extremities and usually results from impaired mechanical stability. Atrophic non-union originates due to the devascularisation of the bone fragments.

Hypertrophic non-unions can be corrected most effectively by improving the stability of the fracture site by compression plating or a reamed, locked intramedullary nail. Atrophic non-union requires both stabilisation and bone-inducing and conductive agents.



20.5 (a) A simple unilateral uniplanar external fixation system in which the pins have been fixed directly to a single connecting rod. (b) Two pins with a connecting rod form a partial frame for each fragment. (c) External fixation being used to stabilise a proximal tibial fracture prior to definitive internal fixation. ⏎

FRACTURE IMMOBILISATION AND FIXATION

External splintage

Immobilisation is an essential part of primary care for unstable and painful skeletal injuries. In addition to non-operative treatment, it is often used perioperatively in trauma treatment, reconstruction, wound care and treatment of infection. If a fracture requires immobilisation, an external plaster-of-Paris splint is the easiest method once the fracture has been reduced.

To immobilise a fractured shaft of a long bone, both the distal and the proximal joints must be covered by the plaster. It is possible to effectively immobilise fractures near a joint by using a cast that includes that joint but stops short of the second joint. In the case of a tibial shaft fracture, for example, a plaster-of-Paris splint is required that includes both the knee and the ankle. By contrast, a malleolar fracture only requires a cast below the knee, while a tibial plateau fracture requires a plaster cylinder above the ankle.

External immobilisation following surgery is still recommended for the protection of healing tissues, to prevent contractures and to aid in functional recovery. It is necessary for the surgeon to be familiar with both traditional plaster-of-Paris and fibreglass plasters and splints. If the cast is poorly applied or planned, it may not provide the necessary immobilisation. Furthermore, pressure sores, nerve palsies, contractures or compartment syndrome are also possible complications. A plaster cast needs to be well padded, not too tight and bivalved if necessary, and care instructions need to be provided.

External fixation

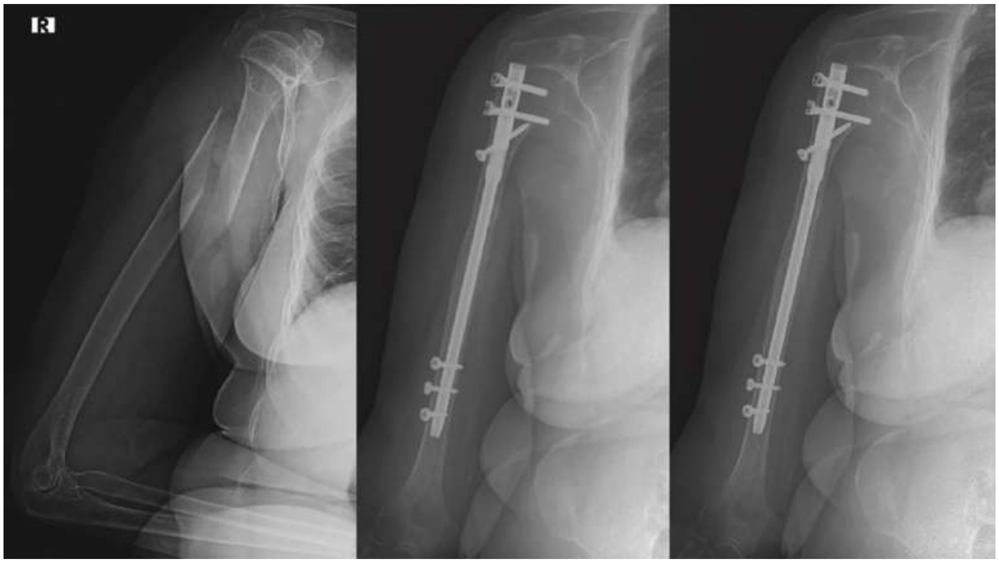
An external fixator is a device that stabilises bone fragments by attaching wires or pins to longitudinal bars and tubes (Figure 20.5). Wires must be tensioned when used. Additionally, external fixation has been used temporarily to stabilise fractures prior to internal fixation and for secondary deformity correction.

The advantages of external fixation include the following: less damage to the bone blood supply, minimal impact on soft tissue cover, useful for stabilising open fractures, optimal for situations in which infection is suspected, and requires less surgical skill and experience than standard open reduction and internal fixation (ORIF). External fixation can be safely used in patients with bone infection.

The disadvantage of external fixation is that pins and wires penetrate the soft tissues. Joint motion is restricted, and pin-track complications are common in long-term fixation. The process is cumbersome and not always well tolerated.

Internal fixation

There are several methods of securing bones internally, including screws, wires, plates and intramedullary rods. Internal fixation offers several advantages, including precise fracture apposition. Healing is generally more efficient and precise without the need to lay



20.6 The X-rays show a right humerus fracture following trauma treated with intramedullary nailing as an internal fixation device. ⏎

down a large mass of callus followed by remodelling. Fractures are stabilised while joints remain mobile, and soft tissue wounds remain more accessible.

Screws transform rotational movement into longitudinal movement. Through the 'lag principle', screws can also be used to compress bone fragments together. Turning the head causes the screw to advance. The lag screw works best when it is passed at a right angle to the plane between the bone fragments. It is possible to achieve internal fixation by using plates and screws, but it is also possible to achieve internal fixation by using intramedullary devices (Figure 20.6). When axially loaded, curved long bones have a compression side and a tension side; plate application on the tension side will convert the loading forces that would otherwise separate the fracture ends into compressive ones.

OPERATIONS ON JOINTS

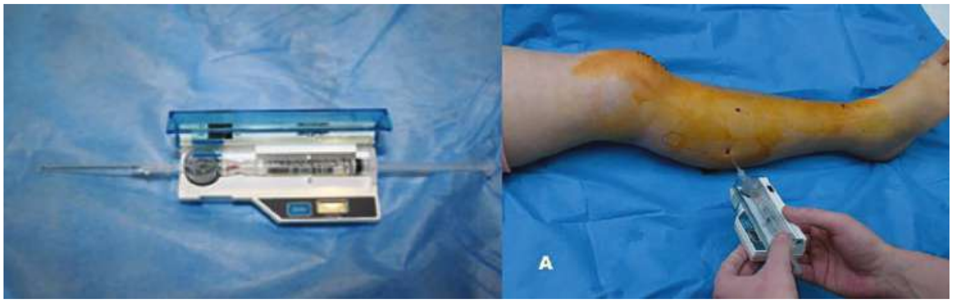
- *Arthrotomy* (opening a joint) may be performed to inspect the inside or perform a synovial biopsy, drain a haematoma or an abscess, remove a loose body or damaged structure (e.g. a torn meniscus) or excise inflamed synovium.
- *Arthrodesis* means fusion of the joints. Occasionally, this may occur spontaneously if inflammation destroys the articular cartilage of a joint. An unstable or painful joint can benefit from this operation. An ideal position for immobilising the joint is crucial for its function.
- *Arthroplasty* is a surgical resurfacing of a joint that relieves pain and restores movement. An excision arthroplasty involves excising sufficient bone from the articulating parts of the joint to allow movement (e.g. Girdlestone's excision arthroplasty, trapeziectomy and proximal row carpectomy). During a partial or hemiarthroplasty, only a part of the joint is replaced (e.g. hemiarthroplasty for an intracapsular hip fracture without acetabular replacement) or one compartment of a joint is replaced (e.g. medial or lateral partial knee replacement). In total joint replacement, prosthetic implants replace all of the articulating parts of a joint (e.g. total hip or total knee replacement).
- *Arthroscopy* is a type of keyhole surgery (similar to abdominal laparoscopy) for checking or repairing joints. Keyhole surgery of any form involves small incisions and telescopic instruments. Arthroscopy is mostly performed on the knees. Arthroscopy can also be performed on the ankles, hips, shoulders, wrists and elbows. Arthroscopy can diagnose and treat a wide variety of joint problems.

A general surgeon whose practice also includes orthopaedics may wish to undertake some of the simpler elective orthopaedic procedures. Unfortunately, space does not permit their inclusion in a general surgical operative textbook, and orthopaedic texts should be consulted.

COMPARTMENT SYNDROME

Compartment syndrome is a frequently encountered emergency for both orthopaedic surgeons and general surgeons. It is crucial to have a comprehensive understanding of the aetiology and fundamental principles in its management.

Compartment syndrome is characterised by increased pressure within a closed compartment, diminishing



20.7 A Stryker compartment pressure monitoring system being used to measure compartment pressures at the bedside. ⏎

microcirculation. Acute compartment syndrome (ACS) occurs when compartment pressure exceeds venous capillary pressure, affecting microcirculation and leading to tissue anoxia, especially in skeletal muscle.

Chronic exertional compartment syndrome (CECS) is a reversible form of ACS triggered by physical exertion. Common in young endurance athletes, especially long-distance runners, CECS symptoms resolve upon stopping exercise and are episodic.

Common sites of ACS include the leg and forearm. Compartment pressures capable of compromising perfusion develop when pressure rises to within 10–30 mmHg of diastolic pressure; muscle oxygenation decreases as tissue pressure approaches mean arterial pressure. The most common cause of ACS is significant trauma associated with long bone fractures.

ACS can be caused by both closed and open fracture treatments. Trauma without fracture, such as severe thermal burns, massive fluid resuscitation, extravasation of intravenous fluids/drugs, constrictive casts/bandage, injury to vascular structures, ischaemic reperfusion injury, animal bites and stings can predispose to ACS.

CLINICAL PRESENTATION AND EVALUATION

Patients with compartment syndrome typically present with pain whose severity appears out of proportion to the injury. The pain is also deep and aching in nature and is worsened by passive stretching of the involved muscles. Ischaemic nerve dysfunction leads to paraesthesia or numbness, with a described tense feeling in the extremity. Traditional signs of acute limb ischaemia (the five Ps: pain, paraesthesia, pallor, pulselessness and poikilothermia) may only manifest in later stages when irreversible soft tissue damage has occurred.

Sensory nerves are affected before motor nerves, and susceptibility varies within the same compartment. Advanced cases exhibit substantial sensory deficit, motor deficit or peripheral pulse loss. Impending ACS may show massive limb swelling with firm compartments as the main sign. In unconscious patients, device-assisted compartment pressure checks are necessary. Muscle ischaemia can lead to rhabdomyolysis, causing myoglobinuria and potential renal failure requiring dialysis.

Clinicians should assess compartment pressures when suspecting ACS, commonly using three methods: a handheld manometer (Stryker device; Figure 20.7), a needle manometer system or the wick/slit catheter technique. Normal compartment pressure is 0–8 mmHg, with capillary blood flow compromised at 25–30 mmHg of mean arterial pressure. Emergency fasciotomy is typically performed if compartment pressure exceeds 40 mmHg or remains at 30–40 mmHg for over 4 hours. ACS delta pressure (diastolic blood pressure minus measured compartment pressure) less than 30 mmHg indicates the need for fasciotomy.

MANAGEMENT

Immediate management of suspected ACS involves relieving external pressure on the affected compartment and removing dressings, splints or casts; avoiding elevating or placing the limb in a dependent position; administering analgesics; providing supplemental oxygen; and addressing hypotension with isotonic saline boluses to enhance tissue perfusion.

Definitive treatment for ACS is fasciotomy, with full decompression of all affected compartments. Delaying fasciotomy increases complications and may lead to amputation. Prophylactic fasciotomy should be considered before the onset of elevated compartment pressure in patients undergoing specific vascular or orthopaedic procedures that are likely to result in a notable increase in extremity swelling, particularly muscle swelling.

LOWER LIMB

The lower limb, below the knee, consists of four compartments (anterior, lateral, deep posterior and superficial posterior) and is a common site for ACS, with the anterior compartment housing extensor muscles and the anterior tibial artery and the deep peroneal nerve being particularly susceptible.

Various leg fasciotomy techniques are described, including single incision with or without fibulectomy and the widely used two-incision method with lateral and medial incisions. Fibulectomy is now discouraged due to the unnecessary risk it poses to the peroneal artery and nerve.

Dual-incision fasciotomy

The dual-incision fasciotomy for the four compartments utilises longitudinal medial and lateral incisions, ranging from 12 to 20 cm in length (Figure 20.8a). The lateral incision is positioned at the midpoint between the fibular shaft and the crest of the tibia. Skin and subcutaneous flaps are developed both medially and laterally to expose the fascia of the intermuscular septum and the fascia of the anterior and lateral compartments. The fascia of the anterior compartment is then incised using either electrocautery or a scalpel. Subsequently, the fascial incisions are extended proximally and distally with scissors, ensuring the posterior blade of the scissors is adequately elevated off the muscle to prevent damage to muscle-associated nerves. Once the anterior compartment is decompressed, a similar procedure is performed on the lateral compartment. Caution must be exercised during the extension of anterior or lateral fascial incisions to avoid injuring the common peroneal nerve or its superficial and deep branches. To minimise the risk of nerve injury, it is recommended to terminate the proximal extent of the fasciotomy approximately 4 to 5 cm distal to the fibular head.

The medial incision in the double-incision fasciotomy is positioned 1 to 2 cm medial to the posterior tibial margin. It is crucial to identify and retract the saphenous vein and nerve to prevent injury. Decompression of the superficial posterior compartment involves making a longitudinal incision in the gastrocnemius fascia from proximal to distal. The deep posterior compartment is decompressed by dividing the attachments of the soleus muscle to the tibia. Figure 20.8b, c demonstrates a tibia fracture stabilised with an external fixator, reducing compartment pressure by immobilising the bone. The fasciotomy incisions are visible, relieving compartment syndrome by decompressing the swollen muscle compartments.

Single-incision fasciotomy

The single-incision four-compartment fasciotomy, despite its one-incision advantage, poses challenges in visualising the deep posterior compartment, increasing the risk of peroneal artery and nerve injury.

In this technique, a lateral leg incision, 1 cm anterior to the fibula, extends from just below the head to 3 to 4 cm proximal to the lateral malleolus. Extensive anterior flaps expose the anterior and lateral compartments. Longitudinal incisions of the fascia, like the double-incision fasciotomy, require careful attention to avoid peroneal nerve injury near the fibular head.

Extending the lateral flap posteriorly accesses the superficial posterior compartment. Gastrocnemius fascia is incised longitudinally, and the deep posterior compartment is reached by creating a plane between lateral and superficial compartments, exposing the fibula's posterior margin. The soleus should be dissected off the fibula. It is important to retract the peroneal vessels posteriorly while performing perifibular dissection to prevent injury (Figure 20.9).

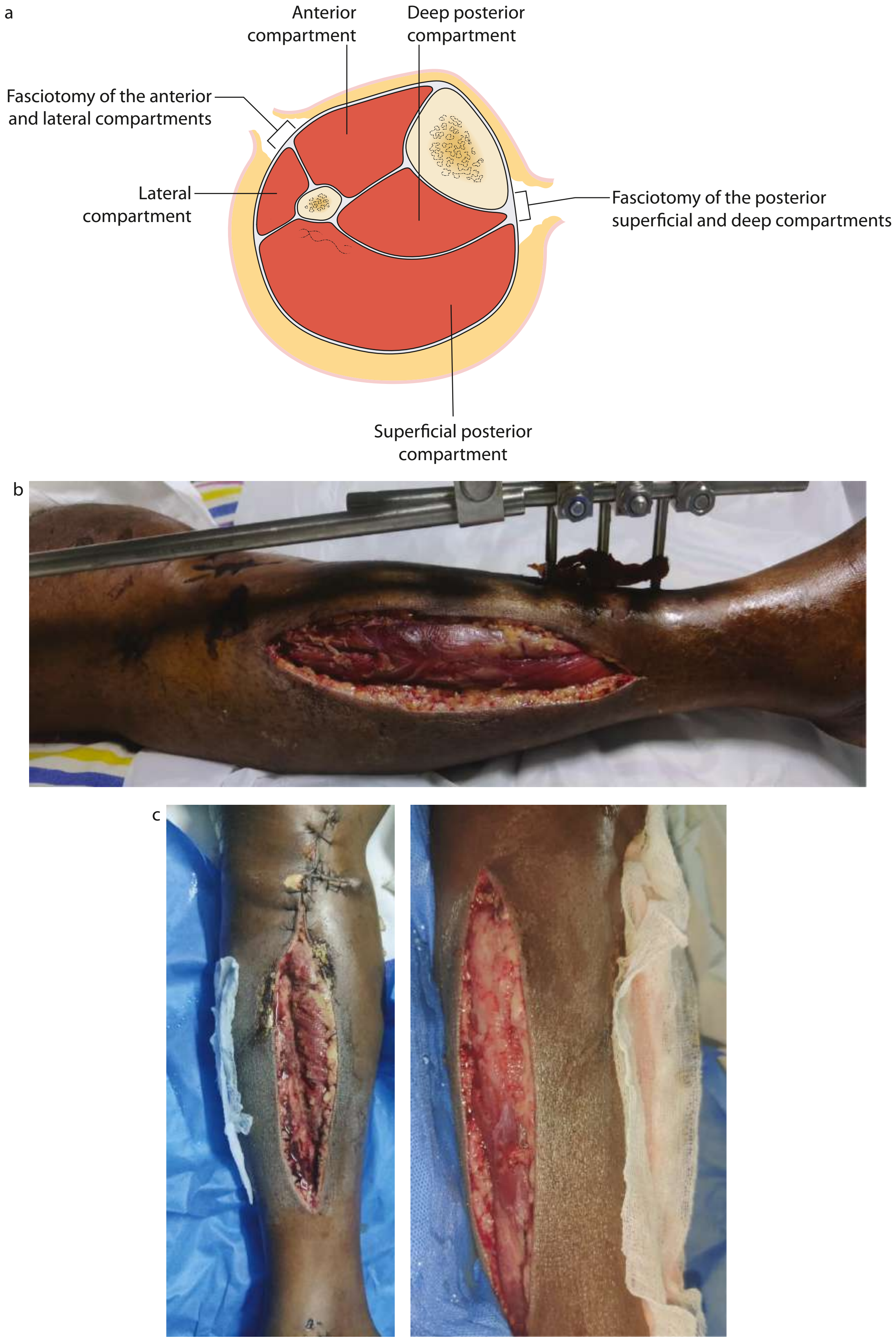
Thigh fasciotomy

Thigh ACS is uncommon but often linked to femur fractures or crush injuries. A single lateral incision, beginning just below the intertrochanteric line and extending to the lateral femoral condyle, is used for decompression. This incision facilitates anterior compartment decompression by cutting the iliotibial band and vastus lateralis fascia. For posterior compartment decompression, the vastus lateralis muscle is reflected medially to expose the lateral intermuscular septum, which is then incised. Given the lower susceptibility of the medial compartment to ACS, measuring compartment pressure is advisable before considering fasciotomy. Decompression of the medial thigh compartment involves a second incision over the adductor muscle group (Figure 20.10).

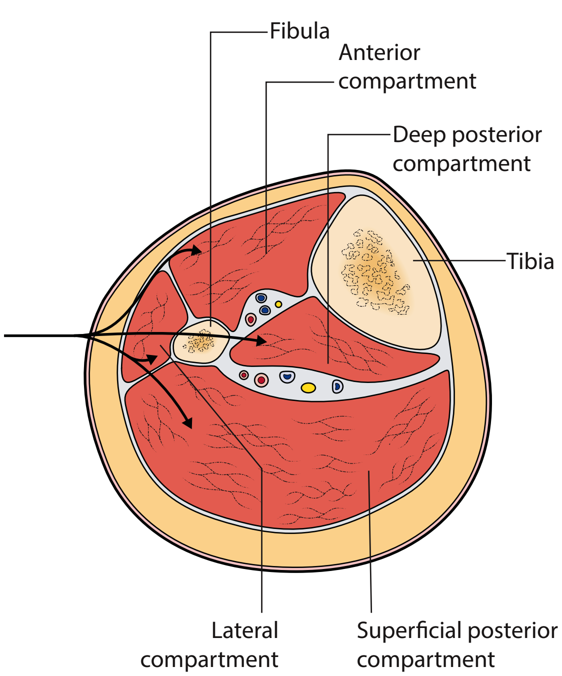
Foot fasciotomy

ACS in the foot, often from crush injuries, may necessitate foot fasciotomy. It can be done dorsally, laterally or medially. Regardless of the approach, thorough opening of each muscle compartment is crucial for complete foot decompression.

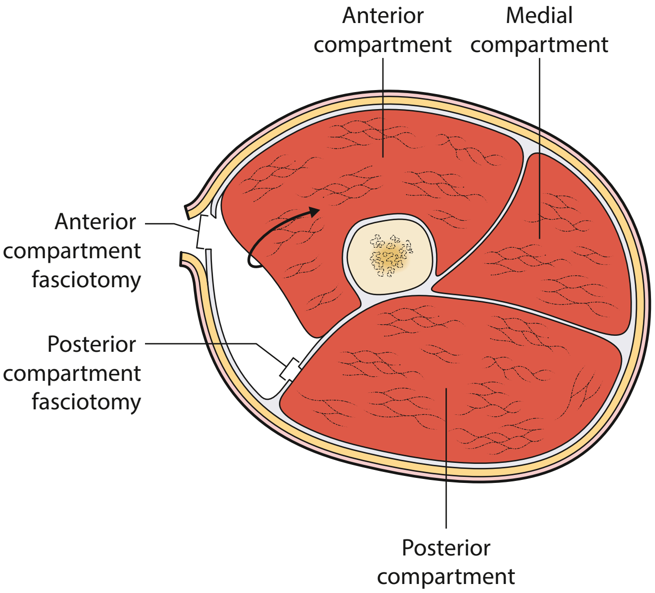
In the dorsal approach, two longitudinal incisions are made strategically, medial to the second metatarsal and lateral to the fourth metatarsal. These incisions provide access to all four sub-compartments of the interosseous compartment and directly open the calcaneal compartment beneath the metatarsals. Access to the medial compartment can be achieved by dissecting medial to the second metatarsal or through a separate incision along the medial foot, immediately posterior to the first metatarsal. Decompression of the lateral compartment is performed through the lateral dorsal incision (Figure 20.11).


a
Anterior compartment
Deep posterior compartment
Fasciotomy of the anterior and lateral compartments
Lateral compartment
Fasciotomy of the posterior superficial and deep compartments
Superficial posterior compartment
b
c

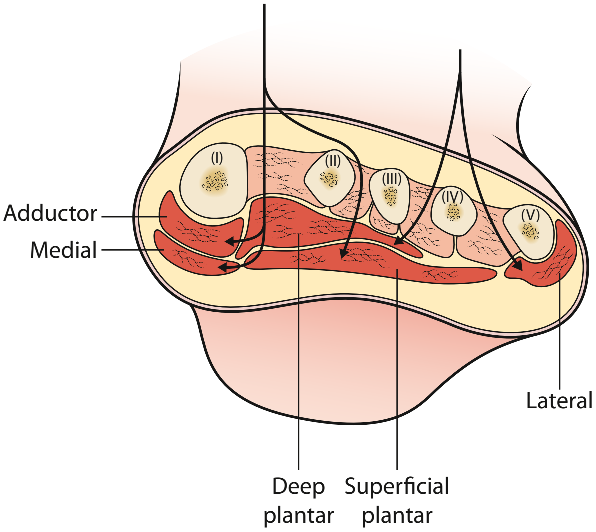
20.8 (a) Dual-incision fasciotomy. (b) A fasciotomy wound with external fixation to stabilise the fracture following trauma. (c) Medial and lateral wounds of a dual-incision fasciotomy postoperatively, awaiting closure. ⏎


Fibula
Anterior compartment
Deep posterior compartment
Tibia
Lateral compartment
Superficial posterior compartment

20.9 Single-incision fasciotomy. ⏎


Anterior compartment
Medial compartment
Anterior compartment fasciotomy
Posterior compartment fasciotomy
Posterior compartment

20.10 Thigh fasciotomy is a relatively rare procedure. However, it may be used in necrotising infections extending above the knee as well. ⏎


(I)
(II)
(III)
(IV)
(V)
Adductor
Medial
Lateral
Deep plantar
Superficial plantar

20.11 Foot fasciotomy dorsal approach. ⏎

UPPER LIMB

Forearm fasciotomy

The forearm comprises four compartments: deep and superficial volar compartments, the dorsal compartment and the lateral compartment, which is known as the mobile wad. The volar compartments are most susceptible to developing ACS, often associated with supracondylar humerus fractures in children and distal radius fractures in adults.

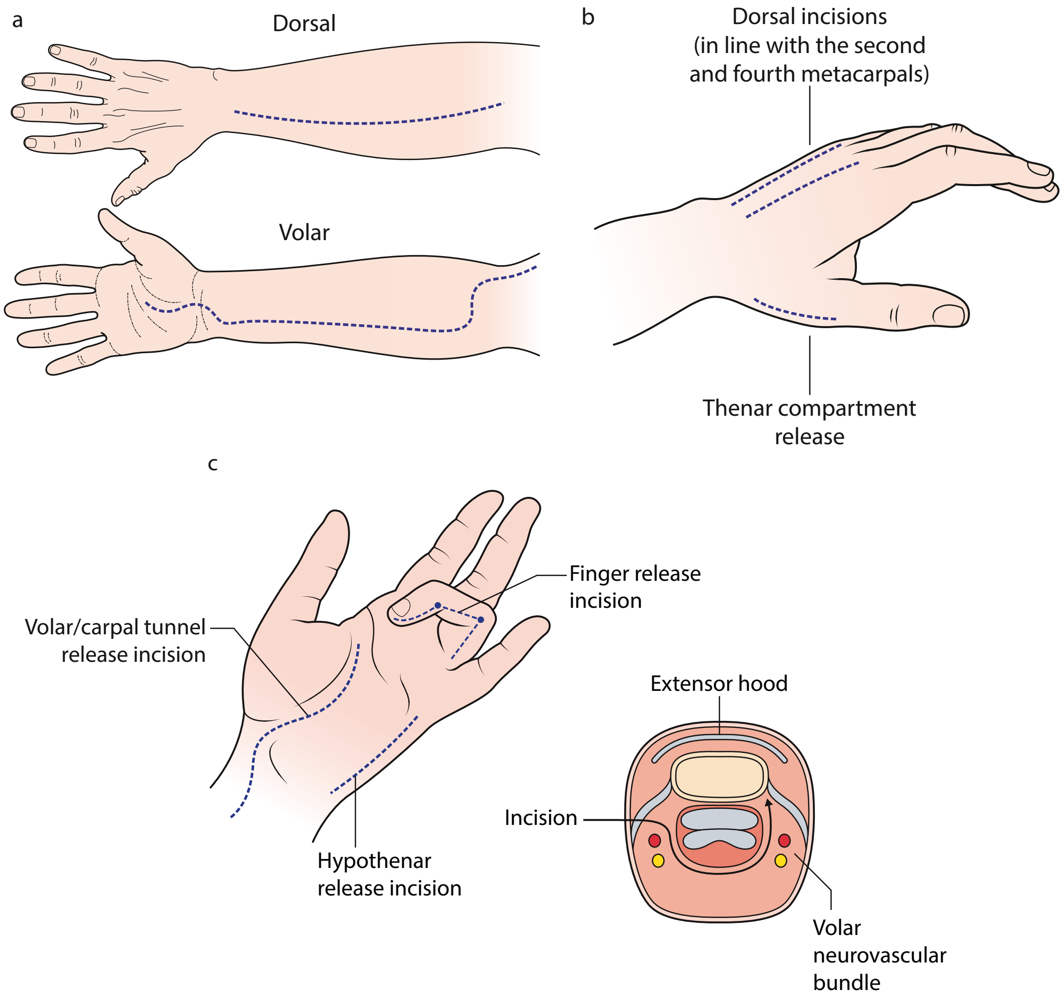
Volar fasciotomy typically involves the volar S incision, a popular approach for volar release. Extending the volar incision or volar ulnar incisions distally to the hand may pose closure challenges and risk exposing the median nerve. This issue can be avoided by employing separate incisions or incorporating a separate hand incision with the volar or volar ulnar approach. For dorsal release, a longitudinal incision is made dorsally, starting 3 to 4 cm distal to the lateral epicondyle, and directed toward the Lister tubercle (Figure 20.12a).

Hand fasciotomy

All seven interosseous and adductor compartments are accessible from the dorsal side, while those containing the carpal tunnel, thenar and hypothenar muscles can be reached from the volar side. The abductor is typically decompressed with either a dorsal or a volar approach (Figure 20.12b, c).

Digit fasciotomy

Decompression of digital compartments involves a mid-axial incision on the non-contact side of the finger to minimise potential adverse effects on digit sensibility. For the index and thumb, the incision is made radially, while, for the middle, ring and little fingers, it is made on the ulnar side. Given that neurovascular bundles are covered by ligaments, it becomes necessary to dissect either ligament while retracting the neurovascular bundles in a volar direction. This approach allows simultaneous decompression of the flexor tendon sheath (Figure 20.12c).


a
Dorsal
Volar
b
Dorsal incisions
(in line with the second
and fourth metacarpals)
Thenar compartment
release
c
Volar/carpal tunnel
release incision
Finger release
incision
Hypothenar
release incision
Extensor hood
Incision
Volar
neurovascular
bundle

20.12 (a) Forearm fasciotomy incisions. (b) Hand fasciotomy incisions. (c) Digit fasciotomy incisions. ⏎

Post-fasciotomy wound care

Fasciotomy incisions can result in sizeable and persistent wounds that may be aesthetically displeasing. Within 48 to 72 hours post-fasciotomy, a relook procedure is advisable to debride non-viable tissues. If no necrotic tissues remain, the skin is loosely sutured; otherwise, alternative closure methods such as negative pressure wound therapy should be considered.

The vascular loop or shoelace technique for dynamic wound closure, using vascular loops secured with skin staples, has been recognised as a viable management option. These loops are gradually tensioned across the wound margins, eliminating the need for skin grafting.

MUSCULOSKELETAL TUMOURS

General surgeons frequently serve as the primary point of contact for patients presenting with musculoskeletal tumours. General surgeons may conduct initial clinical assessments, evaluate suspicious masses and perform biopsies to confirm diagnoses. Additionally, general surgeons may undertake excision of soft tissue tumours that do not involve bone.

It is crucial for surgeons to possess a comprehensive understanding of the management of soft tissue and bone sarcomas. Ensuring referral to a musculoskeletal oncology team after the initial evaluation is imperative, given the significance of multidisciplinary management. Planning biopsies meticulously, determining appropriate margins and ensuring good soft tissue cover are of paramount importance in addressing these tumours.

Musculoskeletal oncology is an extensive subject, and the present summary focuses on the fundamental principles in sarcoma management. A deeper comprehension of the management, considering diverse histologies and tailoring surgical approaches to specific tumour sites, demands extensive knowledge and a multidisciplinary approach.

SARCOMA

Bone neoplasms can be either benign or malignant. Risk factors for the development of soft tissue and bone sarcomas include a history of previous radiation therapy, exposure to certain chemicals (e.g. vinyl chloride and arsenic), immunodeficiency, prior injuries leading to scars or burns, chronic tissue irritation from factors like foreign body implants or chronic infection, Paget's disease and involvement in genetic cancer syndromes like hereditary retinoblastoma, neurofibromatosis, Li–Fraumeni syndrome, etc. However, it is important to note that, in most patients, a specific cause cannot be identified.

Bone sarcomas are typically categorised based on the type of matrix they produce. Sarcomas that generate osteoid are classified as osteosarcomas, while those producing chondroid material are labelled as chondrosarcomas. Tumours originating in both bone and soft tissues exhibit distinct biological behaviours due to their shared mesenchymal origin and the specific anatomical environment. These distinctive patterns serve as the foundation for the staging system and treatment strategies.

In benign lesions, there is a true capsule, which is composed of compressed normal cells, while in sarcomas the reactive zone or pseudocapsule normally surrounds the tumour. This pseudocapsule is composed of compressed tumour cells and a fibrovascular region of reactive tissue with a variable inflammatory component that interacts with the adjacent normal tissues. The thickness of the reactive zone varies based on the histology and malignancy grade. High-grade sarcomas exhibit a poorly defined reactive zone, which facilitates local invasion by the tumour. Within the reactive zone, there are tumour foci known as satellite lesions. In high-grade, and occasionally low-grade, cases, there is the potential for breaking through the pseudocapsule, forming metastases referred to as skip metastases, within the same anatomic compartment as the original lesion. This phenomenon might account for local recurrences that occur despite seemingly negative margins following resection. While low-grade sarcomas frequently interdigitate into the reactive zone, the formation of tumour skip nodules beyond that region is a rare occurrence.

EVALUATION

Assessment of sarcoma involves clinical evaluation encompassing regional lymph nodes and potential distal neurovascular deficits. Imaging modalities comprise X-ray of bones, contrast-enhanced CT/MRI scans of the primary site, CT scans of the chest for metastatic workup and bone scans/positron emission tomography (PET)-CT scans for specific histological subtypes. A preoperative biopsy is deemed necessary if sarcoma is suspected.

BIOPSY GUIDELINES: PREOPERATIVE PLANNING

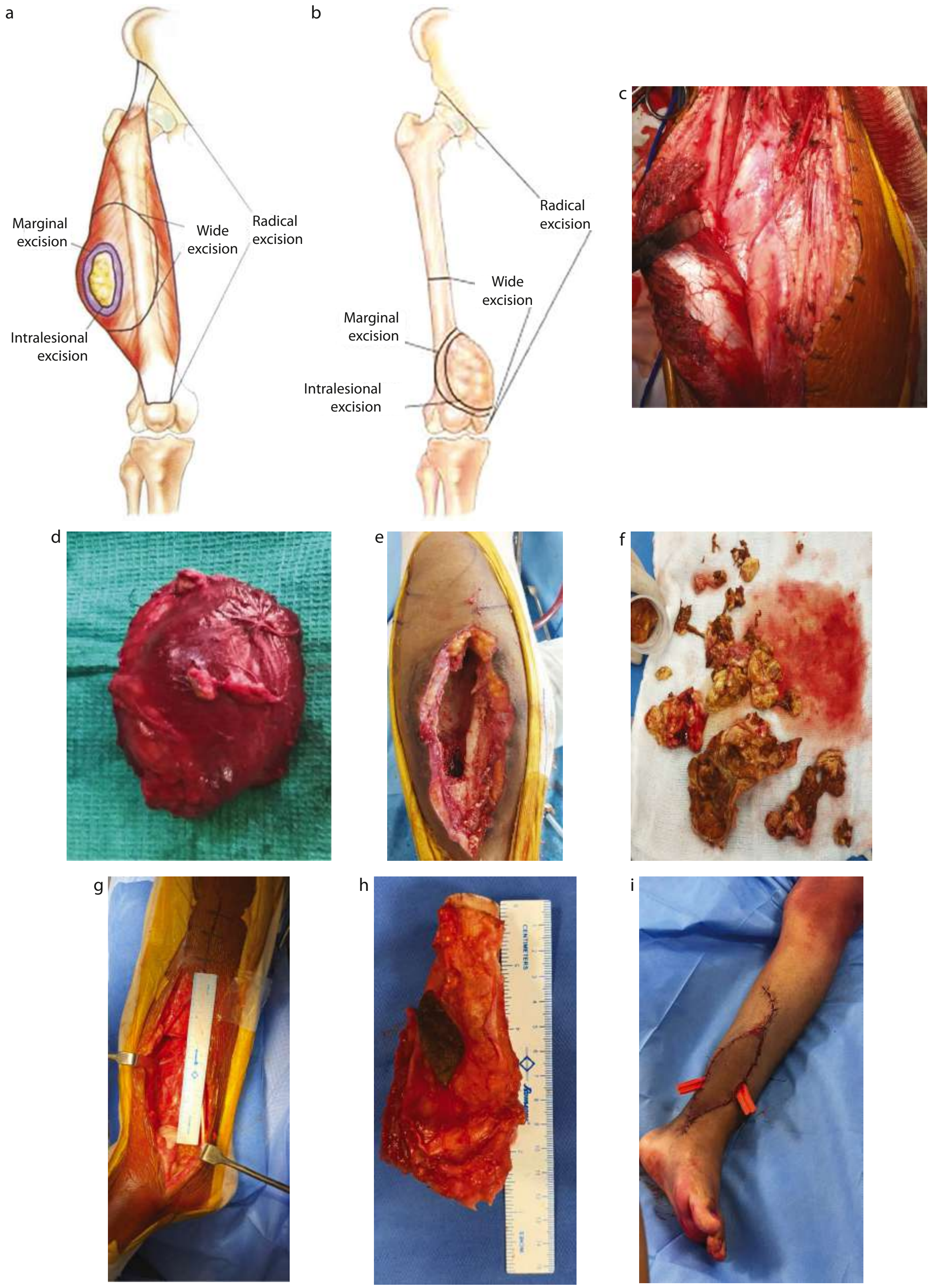
Owing to the morphological heterogeneity of these tumours, obtaining a substantial volume of tumoral tissue, or multiple samples, is necessary when performing a needle biopsy to accurately diagnose the condition. The term 'sampling error' is used to describe an inaccurate or inconclusive diagnosis resulting from a biopsy specimen taken from a region that does not adequately represent the underlying primary disease.

It is important to use the smallest longitudinal incision possible so that sufficient specimen can be collected. A transverse incision necessitates a more extensive resection of soft tissue during definitive surgery. Be sure to maintain strict haemostasis. Contamination of adjacent compartments should be avoided. Biopsy of a solely intraosseous bone lesion should be performed using a cortical window, taking care to avoid fractures. A knife or curette should be used to avoid crushing the specimen or distorting its texture.

CLASSIFICATION OF SURGICAL PROCEDURES

Four primary types of excisions are employed based on the relationship between the dissection plane and the tumour with its pseudocapsule: intralesional, marginal, wide and radical excisions (Figure 20.13a, b):

- In *marginal excision*, the dissection plane passes through the pseudocapsule, potentially leaving microscopic disease.
- *Wide* (en bloc) *excision* removes the tumour, its pseudocapsule and a cuff of normal tissue in all directions, typically 0.5 to 2 cm for sarcoma resection (Figure 20.13c, d).
- *Intralesional excision* removes only a portion of the tumour, performed within the tumour mass, leaving the pseudocapsule and macroscopic tumour behind (Figure 20.13e, f).
- *Radical excision* involves removing the tumour and the entire anatomic compartment in which it arises, eliminating the risk of skip metastases.


a
Marginal excision
Wide excision
Radical excision
Intralesional excision
b
Radical excision
Wide excision
Marginal excision
Intralesional excision
c
d
e
f
g
h
i
CENTIMETERS

20.13 (a,b) Various levels of excision for bone sarcomas. (c,d) After wide excision of soft tissue sarcoma from thigh and resected specimen entirely covered by a cuff of muscle all around. (e,f) Intralesional curettage from proximal tibia. (g,h,i) Tumour excision from the distal tibia followed by reconstruction using a vascular fibula with skin paddle. (a, b From Shmookler B et al. Bone and soft-tissue sarcomas: epidemiology, radiology, pathology and fundamentals of surgical treatment. In: Malawer M, Sugarbaker PH (eds) Musculoskeletal Cancer Surgery. Treatment of Sarcomas and Allied Diseases. 2001. With permission of Springer Nature BV.) ⏎

GUIDELINES FOR LIMB SALVAGE SURGERY

Limb-sparing surgery involves sequential stages:

- Tumour resection with clear oncological margins
- Reconstruction, and stabilisation of involved bone and joint
- Restoration of the soft tissue envelope for prosthetic coverage and function. The surgeon may be involved in some stages of the procedure

It is essential that the major neurovascular bundle is tumour free. It is recommended to perform a wide resection of the affected bone while maintaining a normal muscle cuff in all directions. The resection may be a planned marginal excision at certain areas to ensure limb salvage is possible. All prior biopsy sites should be removed along with potentially contaminated tissues at the same time. The bone should be resected with a margin of 2 to 3 cm beyond the abnormal uptake seen on an MRI or bone scan that has indicated that the tumour has involved the bone marrow. The joint capsule and its adjacent joint must be resected. To achieve adequate motor reconstruction, regional muscle transfers must be performed. To minimise the risk of secondary wound infections and skin flap necrosis, ensure adequate soft tissue coverage (Figure 20.13g–i). If drains are needed, position their entry ports in line with the skin incision, avoiding an angular placement.

METASTATIC BONE DISEASE

A surgeon may encounter patients with metastatic bone disease. A thorough history and physical examination, as well as an assessment of functional ability, may be required. The patient's medical oncologist should be consulted about current oncological status and prognosis. Hypercalcaemia should be ruled out by laboratory tests. Plain radiographs of the affected bone and a total body bone scan should be performed before surgery.

If lytic long bone metastases indicate an impending fracture, surgery is required. Mirels criteria make up a scoring system based on four components of a metastatic lesion: anatomical location, size, radiographic appearance and pain. This scoring system is used for predicting the risk of impending pathological fractures of long bones. During surgery, prioritise resection of the tumour, followed by cemented internal fixation for reconstruction; biological reconstruction is not recommended.

AMPUTATIONS: INDICATIONS AND GENERAL CONSIDERATIONS

Amputation of a limb, or part of a limb, is necessary when injury, disease or pathology threatens the vitality of the extremity, endangers the patient's life or renders the limb non-functional or a source of significant pain and disability. The classic criteria for amputation, known as the 'three Ds', developed by Alan Apley include situations in which the limb is deemed (1) dead, (2) dangerous or (3) a damned nuisance.

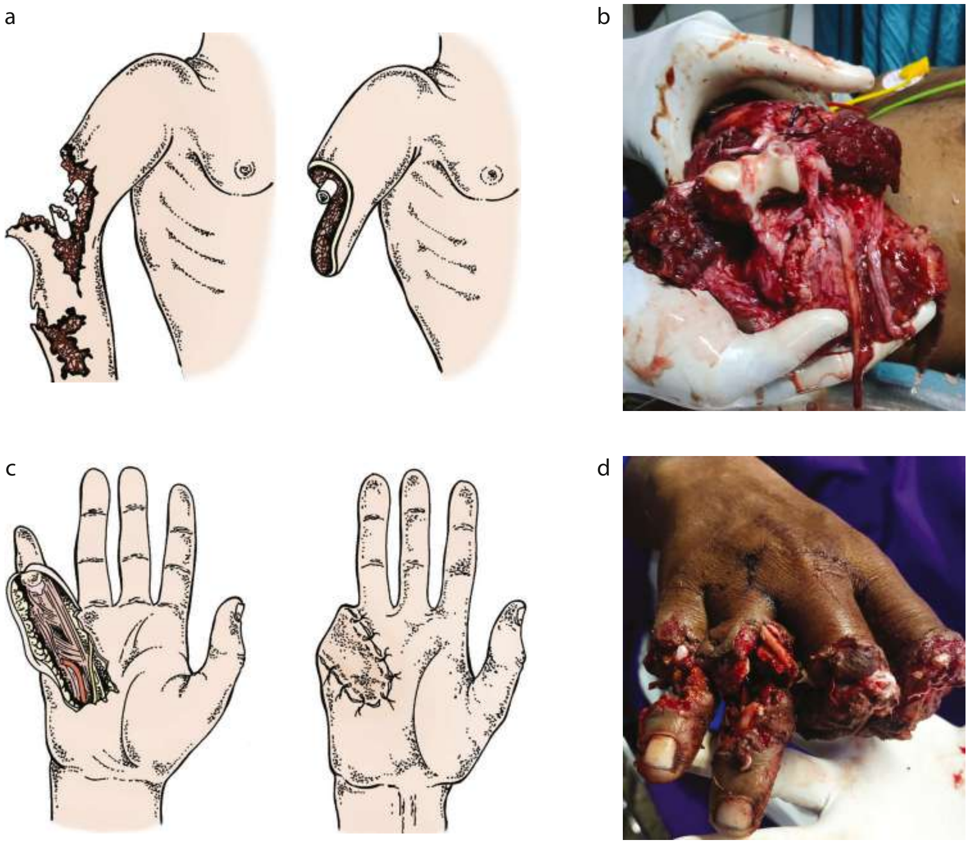
Peripheral vascular disease, trauma, burns, frostbite, malignant tumours, severe sepsis and crush injuries are common causes. Retaining a limb may be more problematic than amputation due to factors such as pain, malformation, recurrent sepsis or severe loss of function, particularly in cases of deformity and loss of sensation, which can lead to pressure ulceration.

In considering the indications for amputation it is necessary to make a clear distinction between the upper and lower extremities. It is important to preserve length and stability in the lower limb. Stability and length are not crucial to useful function in the upper limb, and a grossly deformed or shortened limb is often of more use than a prosthesis. However, retention of a paralysed upper limb is of little benefit to the patient who may request an amputation.

TRAUMATIC AMPUTATIONS

In cases of severe trauma (Figure 20.14a, b), deciding between limb salvage and amputation is complex. Repairing vessels and nerves is possible, and reattaching a completely severed limb, especially from a sharp amputation, can be considered. However, when blunt trauma severs bone, along with causing vascular and nerve damage, salvage surgery outcomes are often disappointing. If bone division is already completed, amputation at that level is acceptable if adequate soft tissue cover is feasible (Figure 20.14c, d). Soft tissue considerations may dictate bone division level in other situations. In some instances, stump length may need adjustment for future prosthetic use but, generally, extra length is advantageous.

For recent and relatively clean trauma, definitive soft tissue closure with a few loose sutures may be possible after meticulous wound care and antibiotic cover. However, if a patient presents late, it is wise to excise non-viable tissue initially and defer the definitive stump creation for several days. In cases where trauma mainly injures a major vessel with unsuccessful vascular reconstruction, amputation may be necessary for ischaemic concerns. Since most trauma



20.14 (a) In severe trauma, bone division is often complete and dictates the level of amputation. A single flap may make the best use of viable soft tissue. (b) Traumatic below-elbow amputation at initial presentation. (c) Severe soft tissue loss of palmar skin and tendons necessitates a proximal amputation despite intact bone. (d) Traumatic injuries to the extremities may have varied presentations and necessitate flap planning based on available soft tissue. ⏎

patients may be young and active, they lack the generalised advanced atherosclerosis complicating most limb ischaemia amputations.

AMPUTATIONS FOR MALIGNANCY

For most soft tissue sarcomas, removing a compartment of soft tissue serves as sufficient local treatment. However, in bone sarcomas, advanced reconstructive techniques have enabled radical bone excision while preserving the limb. However, there are instances where limb amputation remains the sole surgical option. For instance, in cases of subungual melanoma, a distal digital amputation is required to achieve a radical tissue margin.

AMPUTATIONS FOR INFECTION

Amputation becomes a crucial, life-saving intervention in cases of infective gangrene. The swift deterioration of the patient results from the systemic absorption of chemicals released from dead tissue. Delaying amputation inevitably leads to death from multiple organ failure.

AMPUTATIONS FOR PERIPHERAL ARTERIAL OCCLUSIVE DISEASE

Over 90% of amputations in the Western world are needed as a consequence of peripheral arterial occlusive disease (PAOD) and diabetes, which often coexist. Surgical or endovascular approaches are pursued to avoid amputations unless irreversible ischaemic damage has occurred. If these efforts fail, or are impractical, an amputation may be considered. When wet gangrene is present, immediate amputation is necessary; when dry gangrene is present, natural resolution may be possible, but surgical amputation is usually recommended. Frostbite can also lead to dry gangrene.

In patients with widespread, multilevel arterial disease, amputation at the most distal level compatible with healing must be the goal. In patients with mostly distal small vessel disease, conservative amputations may be considered. Older patients with compromised mobility and cardiorespiratory reserve often regain mobility after below-knee amputations, but rarely after above-knee amputations. The energy expenditure required may cause patients with more proximal amputations to be wheelchair bound. When possible, preserving the knee joint will reduce energy expenditure significantly. Occasionally, an above-knee amputation may be appropriate for patients who are unable to fit limbs or recover full mobility. The focus is on improving transfer skills and using wheelchairs after the procedure. Those with PAOD often have widespread pathology throughout their arterial system, leading to high perioperative mortality and poor late survival after amputation.

SURGICAL PRINCIPLES OF AMPUTATIONS

Determination of amputation level

It is important to understand the trade-offs between the increased function of distal amputations and the decreased complication rate of proximal amputations when determining the appropriate level of amputation. The overall well-being of the patient, the general health condition and rehabilitation are all important factors. Recent advances in prosthetic design enable prosthetics to be adjusted to fit any sized stump after an amputation.

The key factor in determining amputation level is vascularity, which can be assessed by transcutaneous oxygen measurement, segmental systolic blood pressure or Doppler arteriogram. When performing an amputation for infections, sepsis control is key. The patient's performance status and medical comorbidities should also be evaluated. There are several factors to consider, including nutrition, ambulatory status and aerobic capacity. When performing surgery for a tumour, adequate margins are required.

Those who prioritise ambulation should consider amputation at the most distal level. An emphasis on wound healing and reducing perioperative morbidity is crucial when ambulation is not a priority. Due to increased risks of wounds and skin problems from knee flexion contractures, transtibial amputations are not suitable for patients without ambulatory potential. Compared with transfemoral amputation, knee disarticulation often offers better function. Transfers and bed mobility are made easier with the longer lever arm and balanced musculature. Knee disarticulation prevents atrophy and contraction over the femur, unlike transfemoral amputation. Furthermore, through-knee amputation provides better stability and comfort when sitting. However, challenges with prosthesis fitting should be anticipated (Figure 20.15).

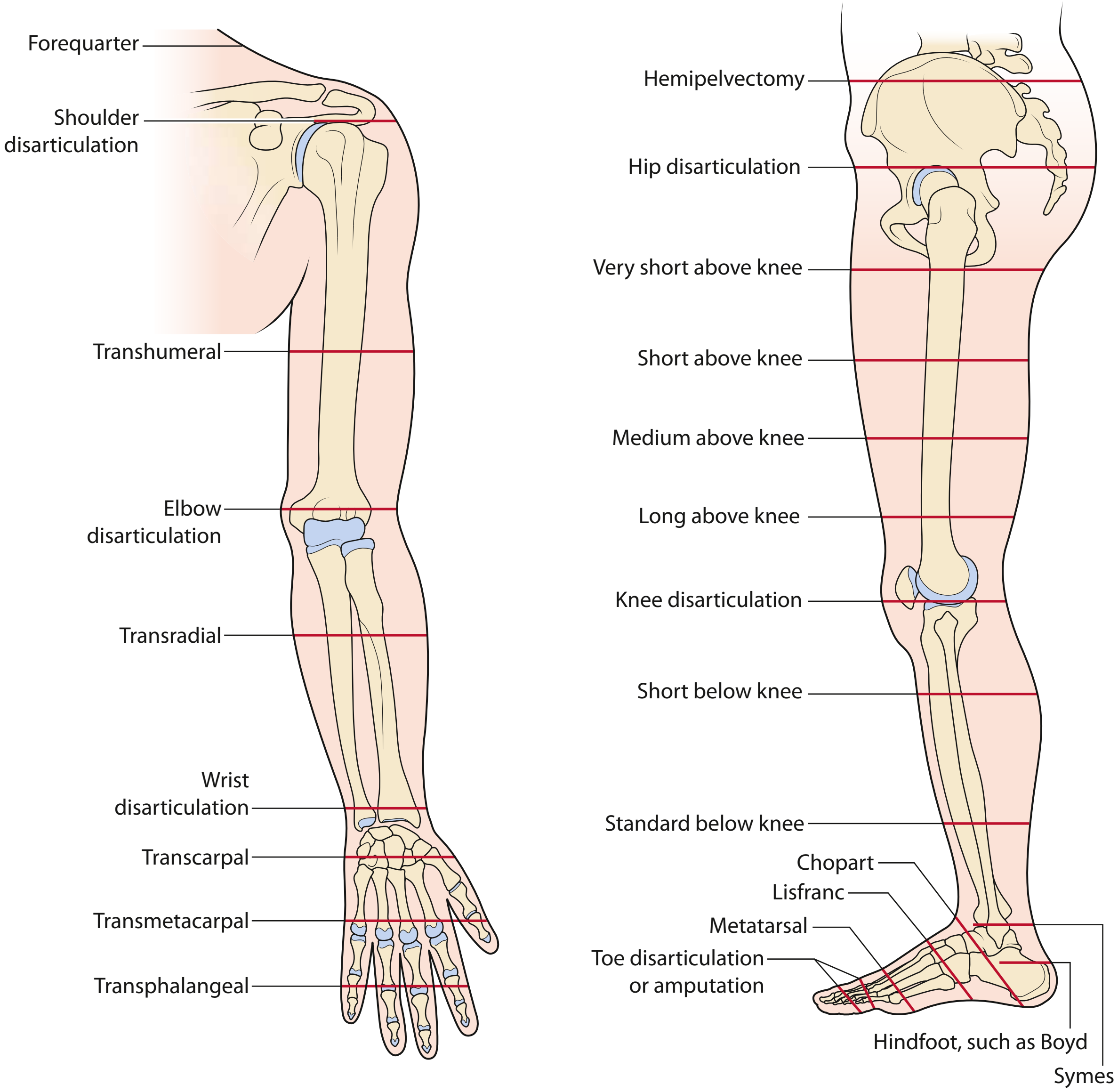
Technical aspects

Stump length Consideration should be given to the desired function of the stump. For instance, even a small portion of a hand holds significant value to the patient and should be preserved. While preserving a weight-bearing heel is valuable, overzealous attempts to save a foot may be misguided. Stumps above the wrist or ankle should be fashioned with the intention of fitting a prosthesis. In the upper arm and forearm, a recommended stump length is 20 cm. For the lower leg, an ideal tibial stump is 14 cm, with stumps less than 8 cm being challenging for prosthesis attachment. In above-knee amputations, a stump measuring 25–30 cm from the trochanter tip is considered optimum. Amputations through joints pose challenges in fitting a satisfactory prosthesis. An osseointegrated prosthetic implant is a biocompatible metal device inserted into the residual bone to integrate with it and attach to an external prosthesis, eliminating the need for socket prostheses and the associated problems (Figure 20.16).

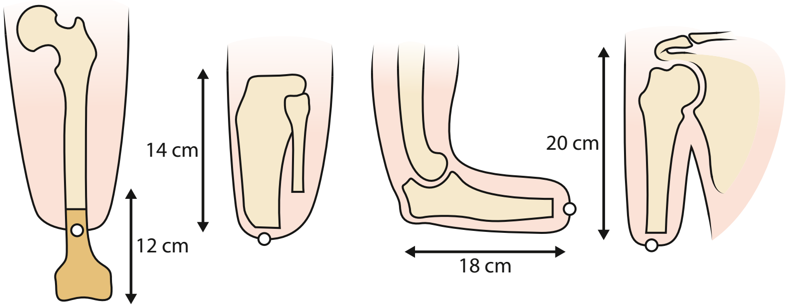
Due to the loss of the distal growing epiphysis in childhood, judging stump length is difficult. Bony overgrowth in an immature stump does not significantly increase length, but periosteal spikes of new bone can cause discomfort, often requiring revision surgery. Preserving as much length as possible is crucial when the major growing epiphysis of the femur is lost during above-knee amputations in childhood. A through-knee amputation is preferable if it is feasible.

Skin and muscle flaps Covering the stump end with a robust soft tissue envelope is crucial. Firmness, smooth rounding and a conical shape tapering distally are characteristics of a prosthetic-ready stump. Excessively bulbous and floppy stumps retain too much muscle and skin distal to the bone division, while bony stumps lack sufficient muscle cover. Flaps should be kept thick to prevent further tissue compromise by avoiding unnecessary dissection. It is less important where the scar lies with modern prosthetic sockets, but an adherent scar to the underlying bone makes prosthetic fitting challenging and may lead to damage over time. Prosthetic fitting and maximal functionality can be impeded by redundant soft tissues or large 'dog ears' on otherwise well-constructed stumps.

Flap planning is very important during amputations and can involve either two flaps cut from opposite sides of the limb or a single longer flap. The combined length of two flaps, or the total length of a single flap, should be 1.5 times the limb's diameter at the bone division level to adequately cover the


Forequarter
Shoulder disarticulation
Transhumeral
Elbow disarticulation
Transradial
Wrist disarticulation
Transcarpal
Transmetacarpal
Transphalangeal
Hemipelvectomy
Hip disarticulation
Very short above knee
Short above knee
Medium above knee
Long above knee
Knee disarticulation
Short below knee
Standard below knee
Chopart
Lisfranc
Metatarsal
Toe disarticulation or amputation
Hindfoot, such as Boyd
Symes

20.15 Levels of amputation. ⏎


14 cm
12 cm
18 cm
20 cm

20.16 The appropriate stump lengths most conducive to fitting a prosthesis. ⏎

bone. To achieve a conical stump, the flaps must be semicircular. Sometimes, unequal flap fashioning is necessary to avoid necrosis or to maximise the use of well-perfused tissue. To ensure equal skin edge lengths for suturing, the shorter flap should be wider than the longer flap. A good blood supply to the skin is crucial for amputations caused by PAOD. A combined myocutaneous flap offers advantages, but the distal muscle may need to be thinned to prevent a bulky stump.

Typically, muscles are divided at least 5 cm distal to the intended bone resection. It is possible to stabilise muscles with myodesis (suturing muscle to bone) or myoplasty (suturing muscle to periosteum or fascia of opposing muscles). It is preferrable to use myodesis for a stronger insertion, maximising strength and minimising atrophy. In severe ischaemia, myodesis may be contraindicated due to an increased risk of wound breakdown.

Nerves A neuroma forms after nerve transection, and it becomes painful if it is subjected to repeated trauma. It is currently accepted among surgeons that nerves should be isolated, gently pulled into the wound, and divided cleanly with a sharp knife, ensuring that the cut end retracts well proximal to the level of bone resection. Preventing post-healing pain in the amputation stump requires avoiding strong tension on the nerve during this process. In addition, crushing should be avoided. Ligation is recommended for large nerves such as the sciatic nerve that contain large arteries. Burying cut nerve ends in muscle to reduce postoperative pain and phantom limb sensation is currently practised by some surgeons.

Haemostasis The use of a tourniquet is very beneficial in amputations, except in cases of severely ischaemic limbs. An Esmarch bandage can be used to exsanguinate the limb before inflating the tourniquet. If the limbs have been amputated due to infection or malignancy, expressing blood from the limbs in this manner is not recommended. For such cases, elevating the limb for 5 minutes should precede inflation of the tourniquet.

Blood vessels Major blood vessels should be isolated and ligated separately, with separate ligations for arteries and veins and double ligations for larger vessels. To ensure thorough haemostasis, the tourniquet should be deflated before closing the wound. Vacuum drains can be used for 48 to 72 hours. Where available, energy devices such as LigaSure, which cut and coagulate muscles simultaneously, can reduce postoperative bleeding.

Bone It is important to avoid excessive periosteal stripping, as it can result in ring sequestration or bony overgrowth. Specifically in the anterior tibia, lateral femur and radial styloid, bony prominences not adequately cushioned by soft tissue need to be removed and the bone rasped to create a smooth contour.

Closure It is necessary to suture opposing muscle groups over the bone ends to cover them and to balance the muscle action on the stump. Younger patients may undergo formal myodesis, which involves passing sutures through drill holes to attach muscles to bone ends. It is crucial to close the skin without tension, and vacuum drainage is recommended after a major amputation. Following surgery, healing is the top priority, along with maintaining mobility in the proximal joints.

OPEN AMPUTATION

When an open amputation is performed, the stump's end is left uncovered, which requires at least two subsequent procedures to construct a satisfactory stump. A first operation prevents or eliminates infection, allowing final closure without wound breakdown. For infections and severe traumatic wounds with substantial tissue destruction and foreign material contamination, open amputations are recommended. Until the stump is fully healed, the patient receives antibiotics and supportive care.

POSTOPERATIVE CARE

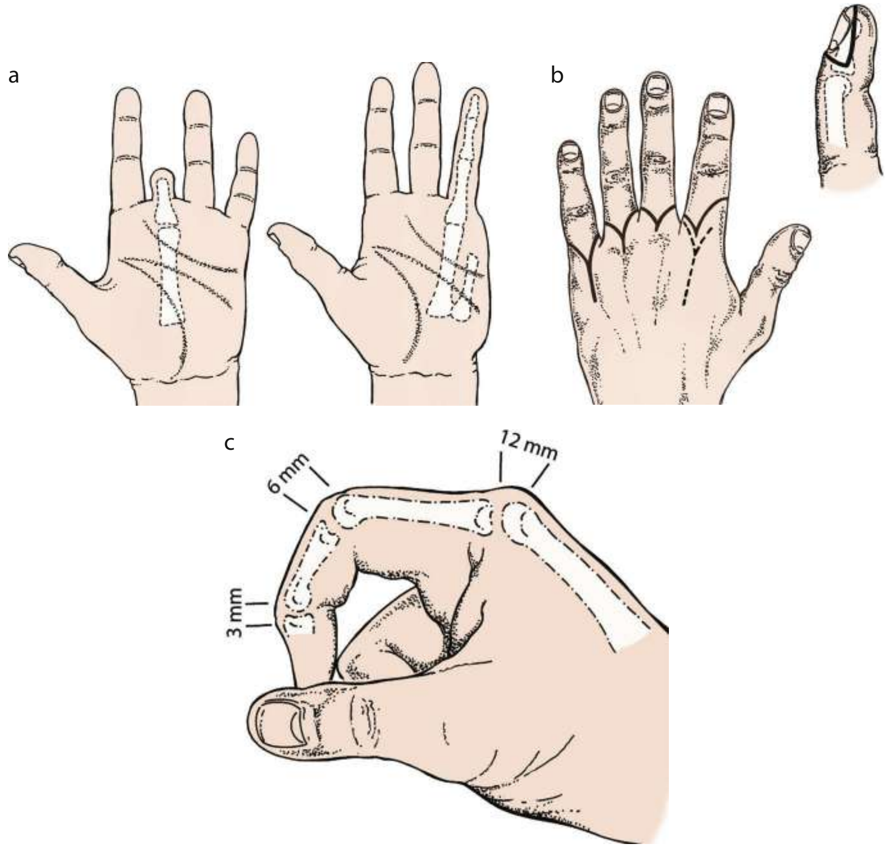
Postoperative care after an amputation typically involves a collaborative team approach, incorporating standard orthopaedic surgery precautions. This includes perioperative antibiotics, deep vein thrombosis prophylaxis and wound care. The first step in pain management is to administer intravenous narcotics, which may be followed by oral pain medications when tolerated.

After surgery, plaster-of-Paris casts are applied as rigid dressings. As part of the cast application procedure, surgeons ensure that proper padding is used, constriction is avoided and reliable suspension methods are used. In addition to preventing oedema, rigid dressings also protect wounds, enhance healing and reduce postoperative pain.

The drains are usually removed after 48 hours, and patients are taught how to position the stump correctly so that oedema and pain can be managed. Physical therapy, starting the day after surgery, includes muscle strengthening exercises and joint mobilisation. Patients are encouraged to mobilise from the bed to a chair as early as possible. For lower extremity amputations, physical therapy begins within days, progressing to ambulation with parallel bars, walkers or crutches. The timing of prosthetic fixation and ambulation depends on several factors, including the patient's age, strength and agility. Skin edges can be treated with negative pressure wound therapy.

COMPLICATIONS

There can be several complications associated with amputations, including haematomas, infections, wound necrosis, contractures, pain, transient phantom limb and skin problems such as dermatitis,



20.17 (a) Amputation through the base of a proximal phalanx gives a strong grip. An oblique metacarpal amputation results in a more satisfactory appearance if the index or little finger must be sacrificed. (b) A single volar flap is preferable for a distal digital amputation. Equal lateral flaps are suitable for more proximal amputations. A racquet extension affords access to the metacarpal head. (c) A surgeon unfamiliar with the surface markings of the joints will have difficulty in planning satisfactory flaps. The measurements given indicate the distance of each joint distal to the angle of the knuckle. ⏎

folliculitis, hyperplasia or warty lesions, and epidermoid cysts.

UPPER LIMB AMPUTATIONS

HAND

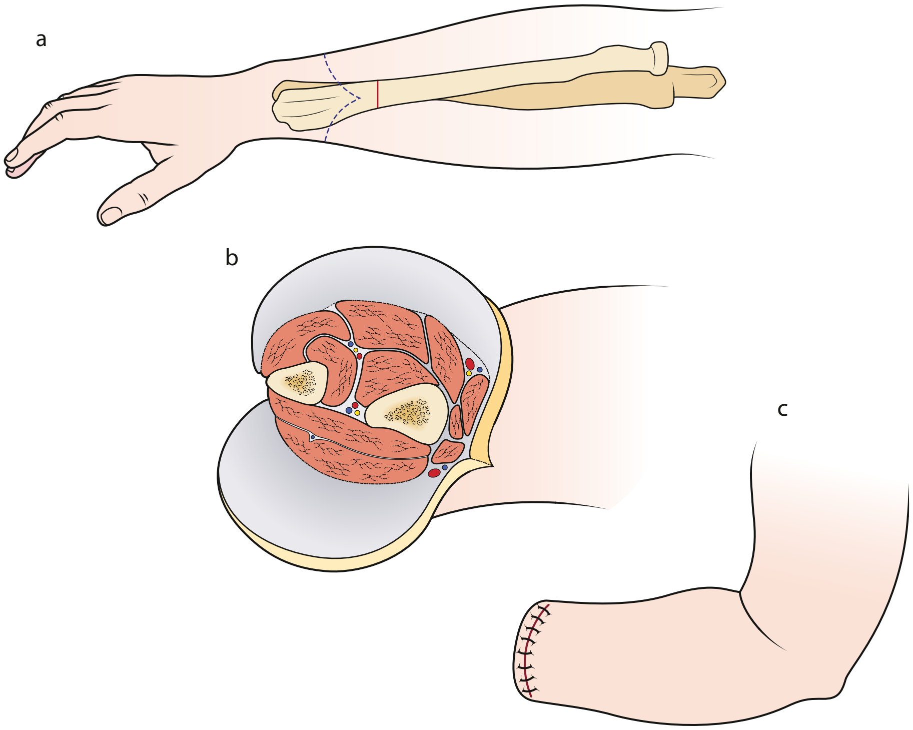
Finger amputations are typically performed when there is severe skin loss and damage to the bones, vessels or tendons. There are many factors to consider when deciding between amputation and reconstruction, such as the extent of the injury, the duration of the ischaemia, the patient's preference and their occupation. There is a preference for covering the bony stump with volar skin depending on the availability of skin and soft tissue. Since the thumb plays such an important role in hand function, it is crucial to preserve as much of the thumb as possible.

Generally, amputations through the base of a phalanx are preferred over disarticulation at the joint proximal to the phalanx. In this way, tendon attachments and intrinsic muscles are preserved, resulting in a stronger grip. It is possible to enhance the cosmetic appearance of the hand by slicing the metacarpal head in an oblique manner while preserving the ligaments and joints of the metacarpal arch. Single volar flaps are suitable for distal finger amputations, while equal lateral flaps are suitable for more proximal procedures. It is crucial to avoid complications by ensuring flap length is appropriate and that joint markings are considered when planning flap placement (Figure 20.17).

WRIST AMPUTATION

When possible, transcarpal amputations or wrist disarticulations are recommended over forearm amputations. In the case of intact distal radioulnar joints, this decision helps preserve pronation and supination abilities. The flexion and extension of the radiocarpal joint are crucial for improving prosthetic functionality in transcarpal amputations.

When disarticulating the wrist, a long palmar and a short dorsal skin flap should be created. The incision is started 1.3 cm distal to the radial styloid process, extended distally across the palm and curled



20.18 The level of a forearm amputation including the cross-section and planning of skin incisions. (a) Distal forearm incision marking; the dashed line indicates the planned fish-mouth incision (longer volar/palmar flap for padding). (b) Cross-section at distal forearm. (c) Postoperative closure; suture line: tension-free, slightly curved (avoiding bony prominence); flaps: volar flap covers bone end and dorsal flap is shorter. ⏎

proximally to end 1.3 cm distal to the ulnar styloid process. The dissection of soft tissues, the division of nerves and the ligation of vessels should be performed according to standard amputation principles. To achieve tension-free closure, the radial and ulnar styloid processes should be rasped or resected. A rasp should be used to smooth out the bone ends. It is essential to preserve the distal radioulnar joint and triangular ligament to permit forearm pronation and supination and prevent joint pain.

FOREARM AMPUTATION

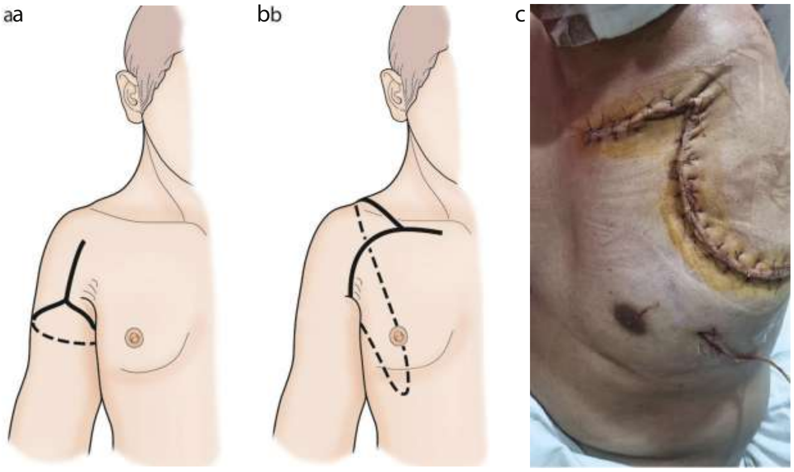
Transradial amputations account for 40% of major upper limb amputations (Figure 20.18). Ideally, it is recommend that at least two-thirds of the forearm length be retained. In cases of severe upper extremity circulation issues, amputations in the distal third of the forearm may not heal as well due to thin skin and limited subcutaneous tissue. In such situations, opting for amputation at the middle-distal forearm junction is preferred. For proximal third forearm amputations, a short below-elbow stump (5 cm) is preferable to elbow or above-elbow amputation, as it preserves elbow function and allows for prosthetic suspension. Maintaining the patient's own elbow joint, including 5 cm of the ulna, is crucial for functional outcomes.

ELBOW DISARTICULATION

Choosing the elbow joint for amputation is advantageous because the broad humeral condyles provide a secure grip in the prosthetic socket, enabling effective transmission of humeral rotation to the prosthesis. In more proximal amputations, transmitting humeral rotation requires a prosthetic elbow turntable. Modern prosthetic techniques have resolved previous fitting challenges at this level, leading most surgeons to generally prefer elbow disarticulation over more proximal amputations. Furthermore, a humeral shortening osteotomy can be performed to preserve elbow function.

ARM AMPUTATION

Transhumeral amputations (Figure 20.19a) involve various levels of removal from the supracondylar region of the humerus to the axillary fold. Prosthetically fitted transcondylar amputations function as elbow disarticulations, whereas more proximal



20.19 (a) The incision for disarticulation through the shoulder joint. (b) The incision for a forequarter amputation. (c) Forequarter disarticulation for tumour. ⏎

amputations function as shoulder disarticulations. An elbow turntable and an inside elbow-lock mechanism are required for the fitting of prosthetics for transhumeral amputees. The turntable provides stability and replaces rotation of the humerus.

SHOULDER

Shoulder-area amputations (Figure 20.19b, c) are primarily conducted for treating intractable malignant bone or soft tissue tumours unsuitable for limb-sparing methods. Opting for amputation through the humeral neck maintains normal shoulder contours and is preferable over more proximal amputations unless specifically indicated. For shoulder joint disarticulation, a racquet incision is employed, starting at the coracoid tip, and extending distally along the humerus to the axillary folds, where it diverges to encircle the arm. The incision deepens to the bone, involving deltoid and pectoralis muscles. The joint capsule and capsular muscles are then divided for humeral head dislocation, followed by securing brachial vessels and dividing nerves and remaining muscle.

Forequarter amputation is a more radical procedure, eliminating the entire upper extremity between the scapula and chest wall. It can be approached anteriorly by detaching the pectoralis major muscle, performing a clavicular osteotomy and identifying the brachial plexus and subclavian vessels. The posterior approach involves detaching the scapula from various muscles, lifting it from the chest wall and checking for chest wall involvement. Both approaches allow the surgeon to proceed with the planned amputation.

LOWER LIMB AMPUTATIONS

FOOT AND ANKLE

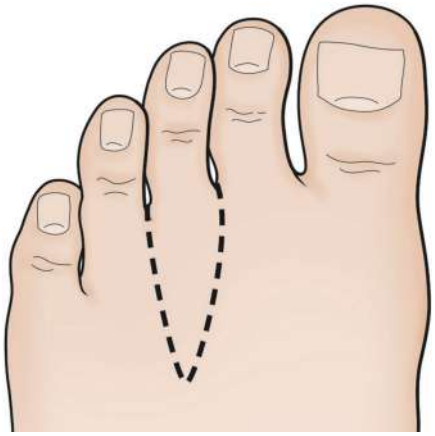
Amputating a single toe typically has minimal impact on stance or gait, except for a potential limp during rapid walking or running after great toe amputation. Second toe amputation may lead to severe hallux valgus. Toe amputation is a predictor of future limb loss, and amputating all toes usually requires no prosthesis beyond a shoe filler. Amputation involving more than two rays is often more disabling than transmetatarsal amputation.

Amputation through the metatarsals is disabling proportionally to the level of the amputation, with no prosthesis needed other than a shoe filler. Proximal foot amputations above the transmetatarsal level cause significant gait disturbance due to loss of support and push-off. Open Lisfranc or Chopart amputations, with secondary closure, can yield good healing and functional outcomes in diabetic patients.

Preserving the base of the proximal phalanx is often preferred over metatarsophalangeal joint disarticulation, retaining weight-bearing properties, especially in the hallux. It may also slow the deviation of adjacent toes when one of the lesser digits is amputated.

Ray amputation

The most common amputation in the foot is a ray amputation (Figure 20.20) of the affected toe together with the distal half of the associated metatarsal. The procedure includes a longitudinal dorsal incision along the affected metatarsal, extending on the plantar aspect in a curvilinear fashion around the metatarsophalangeal joint. The excised tissue is used to reconstruct the resulting web space between adjacent digits. In patients with infections, the wound is left open. Careful consideration is necessary for first or fifth ray local amputations due to potential healing challenges. Extending the incision along the metatarsal shaft allows for the removal of part or all the first (or fifth) metatarsal. By extending the racquet-shaped incision proximally along the metatarsal shaft, part or all the first (or fifth) metatarsal may be removed.



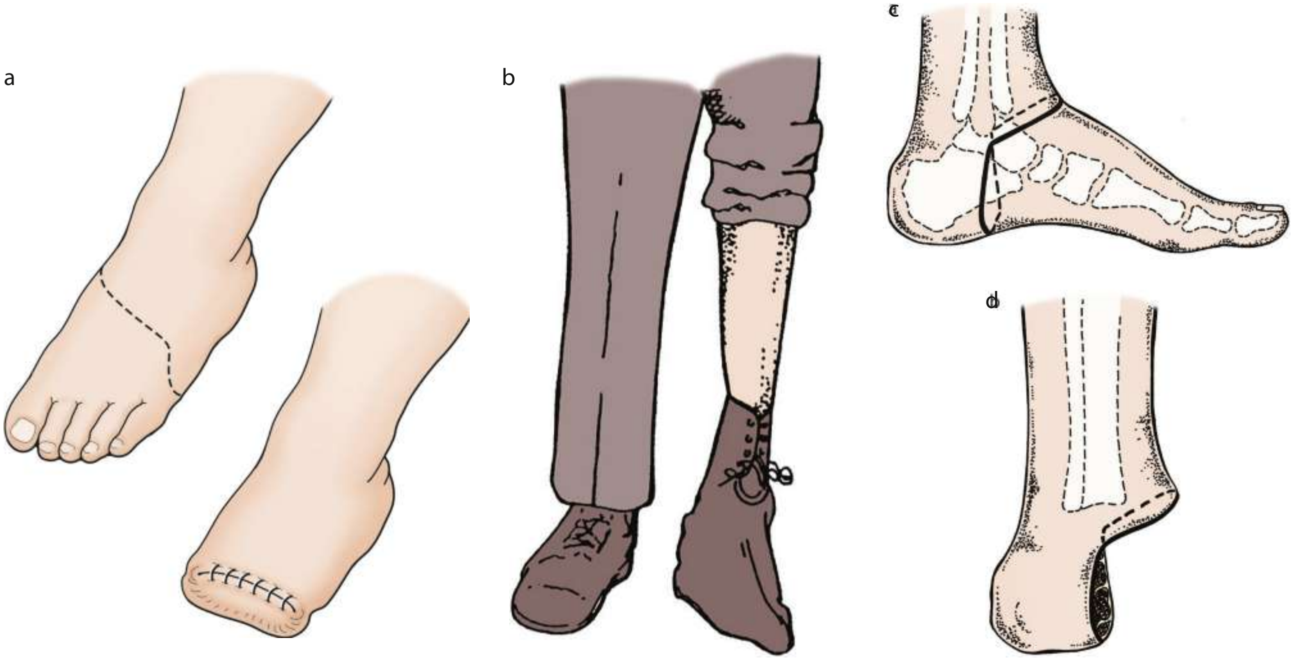
20.20 A ray amputation of a toe together with the distal half of the metatarsal will often suffice if distal gangrene is of infective origin. ⏎

Transmetatarsal, tarso-metatarsal and mid-tarsal amputations

These amputations (Figure 20.21a) provide the patient with a weight-bearing heel. The foot can be amputated at various levels, such as through the mid-tarsal joints (Chopart), tarsometatarsal joints (Lisfranc), metatarsal bones or metatarsophalangeal joints. By utilising a long plantar flap that covers the stump end, the dorsal incision aligns with bone division (Figure 20.21). Minimising equinovarus deformity after a Lisfranc amputation involves preserving the tibialis anterior and peroneus longus insertions at the medial cuneiform and peroneus brevis at the base of the fifth metatarsal. Sparing the base of the second metatarsal maintains the proximal transverse arch. A long plantar flap yields a more effective end-bearing stump, and the natural cascade of metatarsal lengths should be retained.

Syme's amputation

Syme's ankle amputation (Figure 20.21b, c), introduced by Syme in 1842, creates a robust weight-bearing stump, often superior in long-term outcomes to forefoot amputations. It is particularly beneficial for young patients with foot-crushing injuries, especially patients lacking access to modern artificial limbs. The stump's end, positioned about 6–8 cm above



20.21 (a) A transmetatarsal amputation for distal gangrene is only satisfactory if the hindfoot perfusion is good. A single plantar flap has the optimum blood supply and also covers the stump with the skin, which is most suitable for withstanding trauma. (b) A primitive 'elephant boot' prosthesis that was historically used after a Syme's amputation. (c) Syme's amputation incision. (d) In a Syme's amputation, the calcaneum has been dissected out of the heel flap. The malleoli and the distal articular surface of the tibia have been excised. ⏎

the ground, allows walking without a prosthesis or with a simple, cost-effective appliance that elevates the stump. In developed countries, Syme's amputation lost popularity due to challenges in fitting aesthetically pleasing prosthetics.

The incision starts beneath the lateral malleolus, extending across the sole to a point 2 cm below the medial malleolus. The incision meets at the shortest route across the front of the ankle joint, with all structures cut down to the bone. Extensor, flexor and peroneal tendons, as well as anterior tibial and plantar vessels and nerves, are divided, ligated and cut short. The ankle joint is entered anteriorly, and the foot is dislocated in a plantar direction to expose the back of the joint.

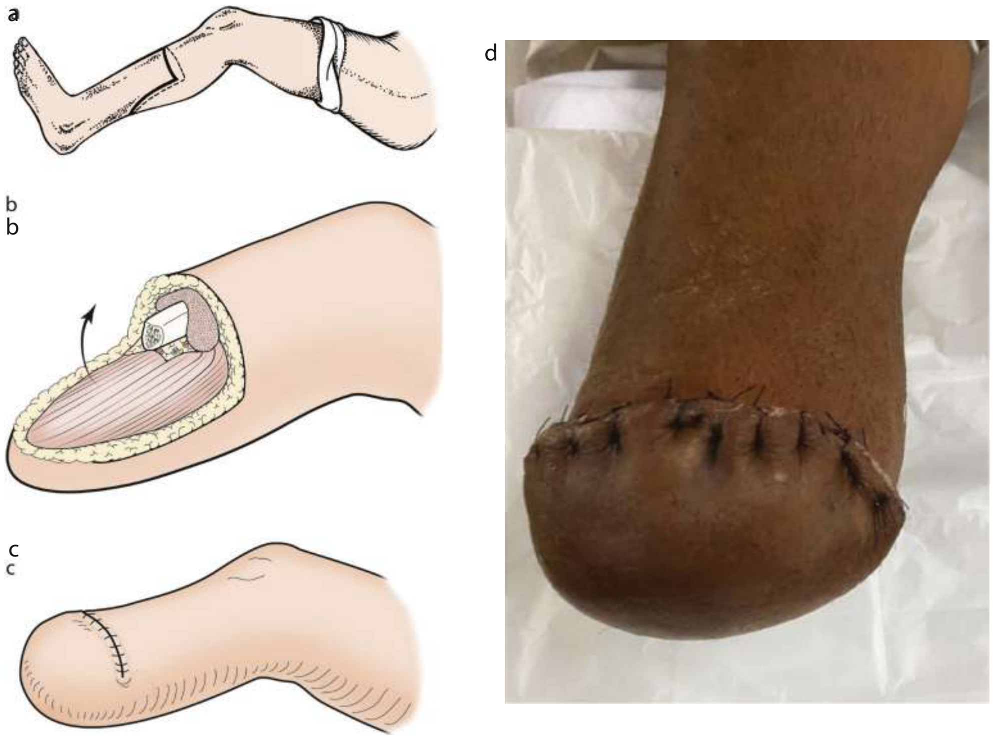
The critical and challenging part involves dividing posterior ligaments, detaching the Achilles tendon insertion and dissecting the calcaneum out of the heel flap. Care is crucial to avoid injuring the posterior tibial and peroneal arteries, located close to the posterior ligament. The branches supplying the heel skin are also at risk during calcaneum dissection. Precision with the scalpel close to the bone prevents damage. Malleoli and a thin slice of the tibia are then removed, and the heel flap is folded over the bone ends and secured in place over a vacuum drain.

BELOW-KNEE (TRANSTIBIAL) AMPUTATIONS

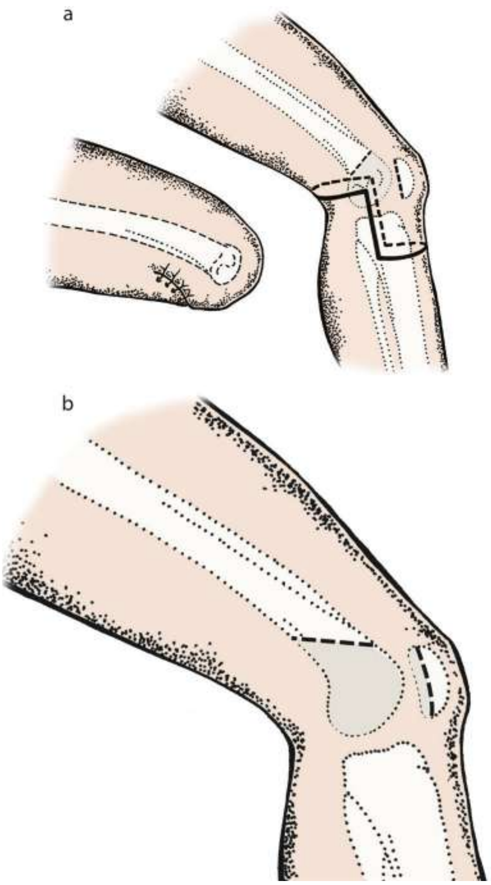
Transtibial amputation (Figure 20.22) is the most frequent lower extremity amputation, often performed for PAOD. The standard techniques aim to optimise the use of well-perfused tissue. While maintaining the ideal 15 cm tibia is not always feasible, having less than 8 cm poses challenges in fitting a satisfactory prosthesis. Careful flap selection is crucial for achieving a functional below-knee amputation stump.

Due to the tibia's subcutaneous location and limited musculature in the anterior leg compartment, a long posterior flap is preferred over a fish-mouth flap. The posterior flap, marked at a length 1.5 times the leg diameter, retains deep fascia and some underlying muscle to ensure skin perfusion. However, muscle bulk is reduced to create a tapered stump. The tibia is divided and bevelled anteriorly, and the fibula is divided slightly more proximally. The arteries encountered are ligated, and nerves are divided for retraction.

Flap muscles are sutured over the bone through the deep fascia, and skin closure is performed over suction drainage. When sawing through the tibia, caution is essential to prevent degloving the skin over



20.22 Below-knee amputation. (a) The single long posterior flap utilises the superior blood supply to the calf skin, which is critical for successful healing in peripheral vascular disease. (b) The posterior muscle groups are divided obliquely from the tibia to the skin to reduce the bulk of the flap. (c) The scar is away from the weight-bearing end. (d) Postoperative below-knee amputation stump showing well-approximated skin flaps and healthy residual limb tissue. ⏎



20.23 (a) Gritti–Stokes amputation. A long anterior flap brings the scar posteriorly. The femur is transected immediately above the condyles. The patella is retained, but its articular surface is removed before it is fixed to the divided femur. (b) A modification in which the femur is transected at an angle to give superior early stability. ⏎

the proximal tibia. Failure to heal is most common at the most anterior part of the suture line.

DISARTICULATION THROUGH THE KNEE

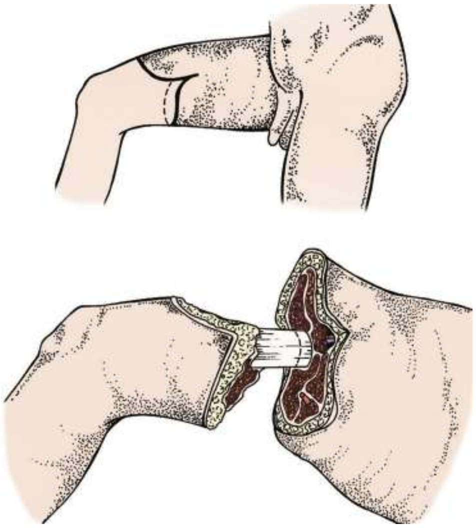
This amputation (Figure 20.23) yields a functionally satisfactory stump capable of supporting end weight bearing. In paediatric cases, through-knee amputation is preferred to preserve final femoral length. Knee disarticulation offers advantages such as preserving large end-bearing surfaces of the distal femur, covered by skin and soft tissues naturally suited for weight bearing; creating a long lever arm controlled by robust muscles; and ensuring prosthesis stability.

The procedure, performed with equal medial and lateral or unequal anterior and posterior skin flaps, involves placing the patient prone. Flaps are raised and access to the joint is from the popliteal fossa, where arteries are ligated and nerves are divided. Posterior muscles and the joint capsule are divided, and the knee is flexed before cutting the patellar tendon at its attachment to the tibia. After dividing the cruciate, medial and lateral ligaments, the amputation is completed. The patella is retained, with the patellar tendon sutured to the cruciate ligaments and the remains of the extensor retinaculum to the hamstrings.

ABOVE-KNEE (TRANSFEMORAL) AMPUTATIONS

These amputations (Figure 20.24) are common for ischaemia and trauma, with varying priorities depending on the circumstances. Generally, a longer stump enhances prosthesis control, and retaining around 70% of the femur (approximately 25–30 cm from the tip of the greater trochanter) is considered ideal. Stumps longer than this pose challenges similar to through-knee amputations. Preserving the entire femur is crucial in children, as previously discussed. While underlying pathology may necessitate upper-third femur amputation, if less than 10 cm can be retained, hip joint disarticulation may be preferred in younger patients for a more satisfactory prosthesis. Conversely, a short femoral stump, even with a flexion deformity, is advantageous for wheelchair-bound amputees.

The operation can use either equal anterior and posterior myocutaneous flaps or unequal flaps with a longer anterior flap (Figure 20.24). Suturing the quadriceps muscle to the hamstrings (myoplasty) maintains balanced muscle action on the stump. In younger patients, some form of more formal myodesis should be considered.



20.24 An above-knee amputation. A two-flap technique is suitable for an amputation through the lower, middle or upper femur. A slightly longer anterior flap avoids a terminal scar. ⏎

DISARTICULATION AT THE HIP JOINT

Hip disarticulation (Figure 20.25) accounts for 0.5% of lower extremity amputations, with varying mortality rates (ranging from 0% to 44%) reported. This radical amputation may be necessary when preserving an insufficient femur for a satisfactory femoral stump. Two classical approaches are commonly used: (1) the anterior racquet method and (2) the single posterior flap method, with the latter potentially offering a more suitable stump for limb fitting. Figure 20.25 illustrates the incisions for both approaches.

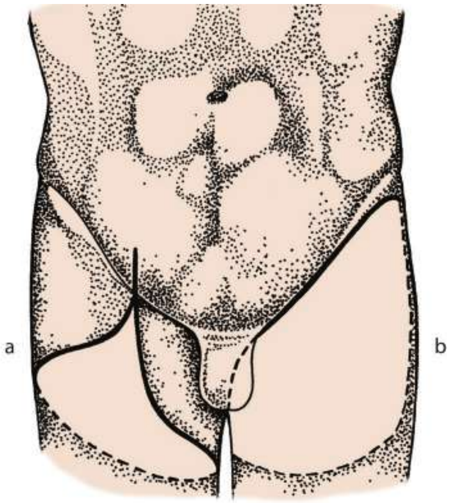
In the anterior racquet incision, the 'handle' aligns with the femoral vessels, and the longer medial flap ensures that the scar falls away from the perineum. Alternatively, the single posterior flap method requires a flap length 1.5 times the anteroposterior diameter of the limb at the hip joint level, with the anterior part of the incision 2.5 cm below, and parallel to, the inguinal ligament.

The initial steps in both methods involve exposing and ligating the femoral vessels. The anterior muscles are divided along the incision line, and the joint is opened from the front. Adductors, hamstrings and the gluteus maximus are cut, leaving portions of the muscles in the flaps. The sciatic nerve is located deep in the gluteus maximus and is cut short. Disarticulation proceeds by dividing the capsule, and remaining short muscles are inserted into the trochanteric area. The flaps and muscles are trimmed to provide reasonable bulk to the stump without being flabby.

HINDQUARTER AMPUTATION

External hemipelvectomy, or hindquarter amputation, is primarily performed for tumours that cannot be adequately addressed through limb-sparing techniques or hip disarticulation. Other indications include life-threatening infections such as necrotising fasciitis and arterial insufficiency. The standard procedure involves employing a posterior or gluteal flap and disarticulating the symphysis pubis, sacroiliac joint and the ipsilateral limb. An extended hemipelvectomy is more extensive by resecting adjacent musculoskeletal structures, such as the sacrum or parts of the lumbar spine. In a modified hemipelvectomy, the bony section divides the ilium above the acetabulum, preserving the iliac crest. On the other hand, an internal hemipelvectomy is a limb-sparing resection, achieving proximal and medial margins equivalent to the corresponding amputation.

This procedure involves an elliptical incision from the iliac crest laterally to the perineal crease medially, using a posterior gluteal or anterior thigh flap. The anterior abdominal muscles are divided, and the deep epigastric vessels are ligated. The symphysis pubis is divided, and the peritoneum and ureter are moved medially to expose the common iliac vessels, which are ligated to reduce blood loss. Alternatively, initial ligation can solely target the internal iliac artery, safeguarding the blood supply of the posterior buttock flap. The ilium is divided through the greater sciatic notch, retaining the major portion of the gluteus maximus. The remaining soft tissue is divided, and all nerves are cut cleanly. Ligation of the external iliac, obturator, gluteal and pudendal vessels is necessary before division, even if the common iliac has been ligated, due to considerable cross-circulation from the other side.



20.25 Incisions that may be used for amputation at the hip. (a) A racquet incision with a longer medial flap. (b) A single posterior flap. ⏎

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Soft tissue surgery: Muscles, tendons, ligaments and nerves

21

Jonathan L Hobby and Kiran Sasi Peringathara

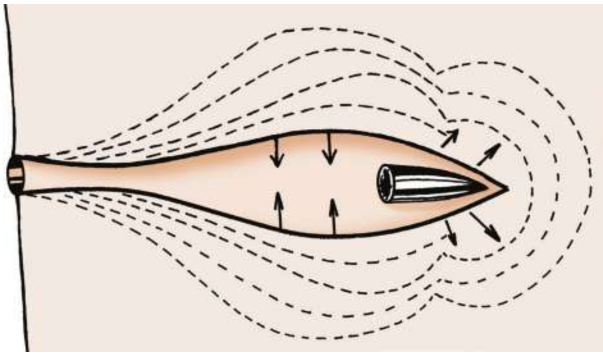
Even though soft tissue injuries are usually managed by orthopaedic surgeons, an understanding of the surgical principles is still essential to the general surgeon. Trauma and infection occur in the soft tissue of both the trunk and the limbs, and there is significant overlap between surgical specialties. This chapter may also be of value to the general surgeon who is unable to obtain specialist help and has to operate in unfamiliar 'orthopaedic territory'. However, the true surgical generalist may find that a large proportion of their surgical practice is in this mainly orthopaedic area and will wish to supplement this chapter with further operative texts.[1]

SURGERY OF SOFT TISSUE TRAUMA

The severity of damage both to muscle and to other soft tissue is often underestimated, as attention is focused on the more obvious skin wound or the fractured bone visible on X-ray. For example, a high-velocity bullet that has passed through the upper calf may have inflicted small entry and exit wounds and a tibial fracture. The fracture appears to be the most significant injury, and initially it may not be appreciated that almost the entire calf musculature is necrotic, that there is nerve and arterial damage, and that the viability of the distal limb is threatened. Soft tissue trauma inflicts three separate insults: direct tissue injury, tissue ischaemia and the introduction of infection. Stabilisation of associated skeletal injuries is a key component in reducing infection in addition to maintaining or restoring the blood supply and achieving soft tissue cover.

DIRECT TRAUMATIC DAMAGE

A knowledge of the mode of injury is a useful predictor of the likely damage. A stab wound with a sharp knife causes minimal damage, except to the tissue that is severed. Blunt injury may produce an area of damaged or even non-viable tissue, with little overlying skin damage. A high-velocity missile imparts kinetic energy to the surrounding tissue and a temporary cavity forms, with traction forces on the tissue and disruption of small vessels. The cavity sucks in contaminants and then collapses. The final result is extensive contaminated tissue death surrounding an apparently small-calibre track (Figure 21.1).



21.1 A high-velocity missile causes extensive damage to the tissue around the track. ⏎

DAMAGE TO THE BLOOD SUPPLY

An injury may sever a major vessel. However, the damage to an artery may be more subtle with only a partial tear in which the distal circulation is initially preserved but later deteriorates (see Chapter 18). Injury to a major vessel in the vicinity of a penetrating wound must always be suspected, especially if there is evidence of nerve damage. More commonly, the swelling of injured soft tissue within a closed fascial compartment (*compartment syndrome*) impedes tissue perfusion as pressure rises.

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INFECTION

Any traumatic injury that breaches the skin or mucosa can introduce infection. However, a sharp injury inflicted with a non-sterile knife seldom results in significant infection. In contrast, penetrating injuries with blunt objects are associated with a high risk of infection, as virulent organisms may be carried into tissue that has also been contused, or rendered ischaemic, by the injury. Infection of damaged tissue leads to further tissue necrosis. Gross contamination, with soil or clothing carried into necrotic tissue, almost inevitably results in severe limb- and life-threatening infection, as the necrotic debris, and haematoma, are an ideal culture medium.

SURGICAL REMOVAL OF DEAD TISSUE AND CONTAMINANTS

The nature of the injury gives a good preoperative indication of the likelihood of extensive soft tissue necrosis or gross contamination. All dead tissue must be excised and all vegetable debris removed, or severe complications are inevitable. A small skin wound may have to be extensively enlarged in order to achieve adequate access. Any tissue of doubtful viability can be left for a second inspection after 24–48 hours (see the section 'Delayed repair' below). Metallic foreign bodies, such as bullets, shotgun pellets and pieces of shrapnel, may remain quiescent for a lifetime and do not always need to be removed, as there is always a risk of causing more damage by attempting surgical removal than that caused by the original weapon.[2] However, it must be remembered that clothing and other contaminants invisible on X-ray may also be in the wound. Rarely, a lead-containing foreign body may cause lead poisoning.

SURGICAL RESTORATION OF TISSUE PERFUSION

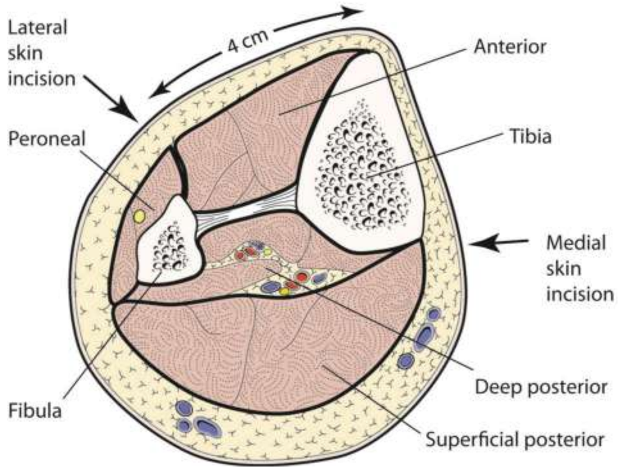
If a major vessel has been severed and there is distal ischaemia, arterial repair is of the utmost urgency if amputation is to be avoided (see Chapter 18). Arterial shunts may be appropriate to restore perfusion. Fasciotomy is usually indicated following revascularisation (see below), as reperfusion almost always results in swelling, which may lead to compartment syndrome, with a risk of loss of the limb and/or acute renal failure.

Oedema and *swelling* occur with any injury and are more marked in blunt injuries with significant tissue contusion. Elevation of the affected part (Figure 21.2), which reduces oedema, remains a mainstay of management in most situations. *Compartment syndrome* is the result of bleeding, or swelling, within a restricted space, leading to excessive interstitial pressure. The critical pressure is that which impairs venous return from the compartment and is approximately 30 mmHg below the diastolic arterial pressure. It can be caused not only by trauma but also by other insults, including even severe, unaccustomed, exercise. The muscles of an acutely ischaemic limb that has been revascularised will also swell later, and the resultant compartment syndrome can lead to the loss of a successfully revascularised limb. Pain that is out of proportion to the injury, and increased by passive stretching of the affected muscles, is the cardinal sign. Urgent decompression by fasciotomy, before irreversible ischaemic muscle damage occurs, is vital if a functional limb is to be salvaged. Minor compartment syndromes may settle with elevation and rest, and the decision on whether to operate is sometimes difficult. The risks of failure to operate are far greater than those of an unnecessary operation.

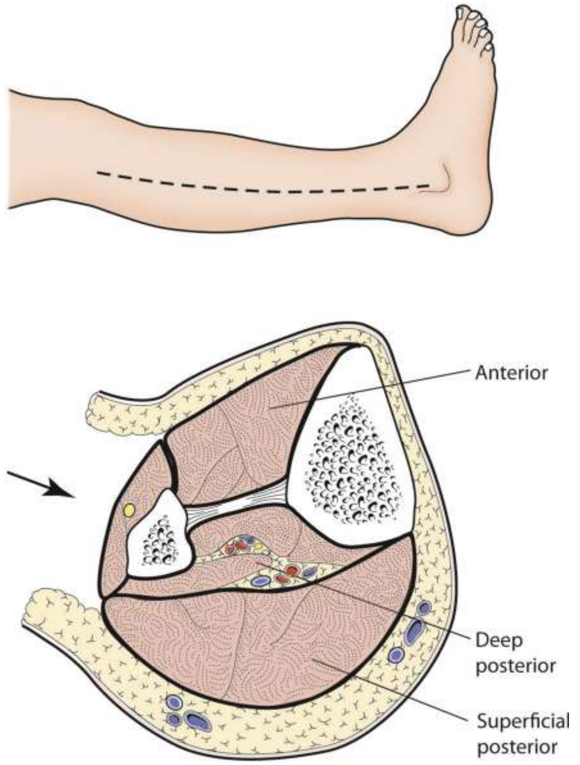
21.2 Elevation of an injured hand. The photograph was taken by Eric Farquharson using a member of his family as the model. ⏎

Fasciotomy

Fasciotomy is the treatment of any significant compartment syndrome.[3] The fascia must be opened along the length of the muscle belly. This can be achieved by a subcutaneous fasciotomy, but it is easier, and safer, to incise the whole length of overlying skin. This will not only release any associated skin constriction but also allow inspection of the ischaemic



21.3 An incision behind the medial border of the tibia affords access to both posterior compartments of the calf. A second incision 4 cm lateral to the anterior border of the tibia is required for access to the anterior and peroneal compartments. ⏎



21.4 A single incision over the fibula with elevation of flaps allows access to all four compartments. ⏎

muscle, which should 'pink up' within a few minutes if decompression is timely. Viable muscle will contract if gently 'pinched' with forceps, but devitalised muscle will remain pale pink and non-contractile. Closure by secondary suture is appropriate after a few days, when the swelling subsides, but skin grafts may be needed. Occasionally, only one fascial compartment is at risk. More often, all compartments need decompression.

In the *leg*, an incision behind the medial border of the tibia can be used to decompress the deep and superficial posterior compartments. A second incision 4 cm lateral to the tibia is required if decompression of the anterior and peroneal compartments is also indicated (Figure 21.3). Alternatively, if flaps are raised at the level of the deep fascia, a single lateral incision will provide access to all four compartments (Figure 21.4). When the peroneal compartment needs to be decompressed, the level of the fibular head should be identified and used as a landmark to avoid damage to the common peroneal nerve as it winds around the neck of the fibula. Although the leg is the most common site for compartment syndrome, it can also occur in the thigh, foot and upper limb. There is a particular risk following crush injuries, gunshot wounds, high-velocity trauma and burns.

SURGICAL REPAIR OF SOFT TISSUE INJURY

Primary suturing

Primary suturing of deep tissues and skin is suitable in clean wounds. It may also be appropriate management, with antibiotic cover, in selected contaminated wounds, but thorough wound toilet combined with excision of devitalised tissue is essential prior to closure. In the presence of contamination, copious irrigation with saline is mandatory. It is not helpful to use pressurised lavage or antiseptic solutions, as these may lead to additional tissue damage and do not reduce infection rates.

Delayed repair

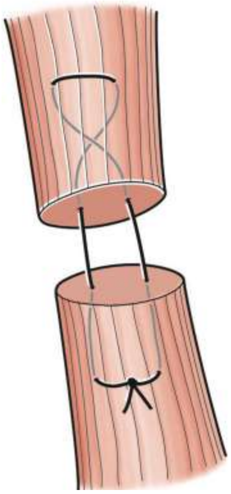
This is always the safer option. Before the advent of antibiotics, delayed repair was considered mandatory for any potentially contaminated wound and for any wound in which wound toilet had been delayed. Antibiotics have merely moved the dividing line between wounds that can be treated by primary closure and those that cannot. If there is established infection and tissue of doubtful viability has been left *in situ*, then primary closure is still potentially disastrous. The wound is cleaned, dead tissue is excised and the cavity is lightly packed with saline-soaked gauze. Forty-eight hours later, the wound is re-explored. If there is no infection and the tissue that previously looked of doubtful viability is now healthy, the deep tissues can be repaired and the wound closed. If, however, there is now further necrosis and infection, the wound is again debrided and left open. If available, negative pressure dressings may be helpful to reduce infection, encourage granulation and manage dead space.

MUSCLE REPAIR

Longitudinal incisions of muscle do not require sutures. A loose suture is at best harmless, while a tighter suture strangulates muscle fibres. However, the overlying fascia may be sutured if there is no significant muscle swelling and closure of the fascia prevents a potential *muscle hernia*. Closed trauma, in the form of a severe force, can cause a transverse muscle belly tear and a knife wound can inflict a transverse laceration. Divided muscle fibres retract and may be noticeable as a 'tumour' proximal to the injury when the muscle contracts. The divided fibres atrophy and there is compensatory hypertrophy of the remaining intact fibres. A surgical repair is therefore usually only indicated for a laceration or tear that has divided a significant proportion of the muscle. When the fascia has also been divided, sutures to appose the fascia may be sufficient to hold the muscle fibres in apposition. The closure of a Kocher subcostal incision is based on these principles (see Chapter 6). If a muscle belly repair is indicated, a figure-of-eight suture will be the least likely to cut out (Figure 21.5). An absorbable suture that loses its tensile strength relatively slowly (e.g. Vicryl™ or PDS™) is suitable. Supervised active motion is recommended, as there will be a risk of adhesions and stiffness if splintage is prolonged. However, it is important to avoid heavy loading (e.g. weight bearing) for 3–4 weeks to avoid rupturing the repair.

RECONSTRUCTION AND TISSUE COVER

This may be best delayed until both the patient and the wound have entered a healing phase, but bone or major vessels exposed by skin and muscle loss may require urgent tissue cover, which can be provided by muscle flaps (see the section 'Muscle flaps'). Any early reconstruction is dependent on a clean wound with a good blood supply.

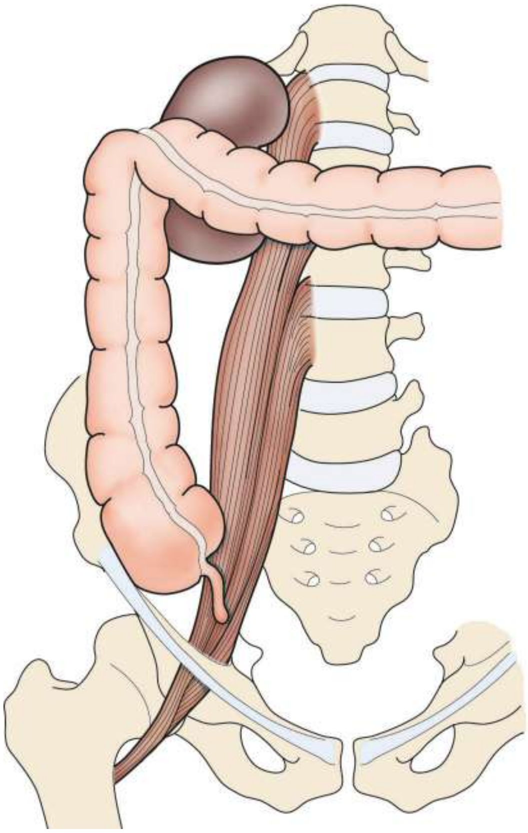


21.5 A figure-of-eight suture is less likely to cut through muscle. ⏎

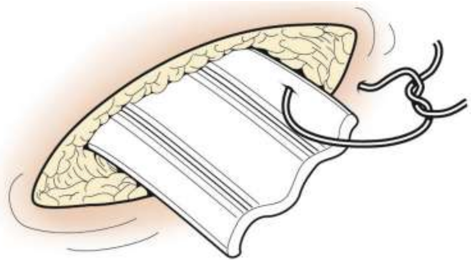
INFECTION OF MUSCLE

PYOGENIC MUSCLE INFECTION

This most commonly occurs secondary to penetrating trauma, even if this is only in the form of a minor puncture wound. Occasionally, pus tracks into a muscle from an adjacent deep abscess. For example, a psoas abscess, although pointing in the groin, is usually secondary to a retroperitoneal infection, which may originate from vertebral, colon or kidney infection (Figure 21.6). In malnourished or immunocompromised individuals, a primary pyomyositis of large muscles may occur, and this is a common condition in some tropical countries. Whatever the aetiology, adequate drainage of pus and excision of any necrotic tissue are indicated. A drain should be secured into the depths of the abscess to prevent premature closure of the track (Figure 21.7).



21.6 Colon, appendix, kidney and vertebral bodies are all closely related to the psoas muscle. Infection originating from them may present as a psoas abscess tracking to the groin insertion of the psoas. ⏎



21.7 A corrugated drain prevents premature closure of the track and of the skin. It can be secured by a suture to the wound edge. ⏎

ANAEROBIC MUSCLE INFECTION

Clostridium perfringens, the causative organism of gas gangrene, and *Clostridium tetani*, the causative organism of tetanus, are found in soil and faeces, and these anaerobic organisms thrive in necrotic and ischaemic muscle. Gas gangrene was a common, and much feared, complication in the battlefields of the First World War.[4] Amputation was thus often considered a safer option than attempting to save a severely damaged limb that was already potentially contaminated with bacterial spores.

Gas gangrene

Clostridium perfringens multiplies in ischaemic damaged tissue. The toxins produced by the bacteria damage previously healthy tissue, which is then colonised, and the infection spreads longitudinally within muscle sheaths. The patient is usually profoundly unwell, and crepitus may be apparent from small bubbles of gas.

Prevention consists of thorough early wound toilet with the removal of all necrotic tissue. A high-risk wound is then left open as described above. Although the organism is sensitive to penicillin, the use of this antibiotic for prophylaxis or treatment may be disappointing, as high blood levels do not reach the dead tissue in which the organism is multiplying.

For this reason, the treatment of gas gangrene is primarily surgical. All infected tissue must be excised as soon as the patient's general condition allows. The patient may be extremely ill, with signs of multiple organ failure, and may require general resuscitation, but a surgical delay of more than a few hours will be counterproductive. This situation can pose a similar dilemma regarding the optimum timing of surgery to that encountered in patients with peritonitis, and this is discussed in Chapter 17. If gas gangrene is suspected, exploration is mandatory. In the early stages, the affected muscle fibres are paler than normal, described as having a lustreless pinkish-grey shade. Later, they become deeply congested, slate blue or frankly gangrenous. Bubbles of gas are apparent. All unhealthy and potentially infected tissue must be excised, as leaving traumatised or ischaemic tissue in the vicinity is an unacceptable risk. The possibility of saving a limb should always be considered, but unfortunately amputation is often the only safe option. Parenteral penicillin is administered at high dosage, and hyperbaric oxygen therapy, if available, may be beneficial.

Tissue gas is not pathognomonic of gas gangrene, as saprophytic, non-pathogenic, gas-forming anaerobes may multiply in necrotic tissue. This scenario is occasionally encountered around a retroperitoneal colonic perforation, and here excision of the necrotic tissue alone is adequate.

Tetanus

Tetanus is the other feared anaerobic infection of contaminated wounds. The incidence shows great regional variation, possibly related to soil acidity, and infection can occur after a very minor puncture wound. Immunisation, antibiotics and antiserum are all effective in tetanus prevention. In established infection, there is no local tissue destruction, and excision of the wound has no great therapeutic merit unless indicated for other reasons. Penicillin is effective in destroying residual organisms, and antiserum will neutralise any unfixed toxin. However, by the time of presentation, much of the toxin is already fixed within the central nervous system, and clinical deterioration will continue for some days despite the administration of antibiotics and antiserum. The mainstay of treatment is the control of spasms and general intensive support.

NECROTISING FASCIITIS

This condition has been discussed in Chapter 4A.

MUSCLE FLAPS

Healthy muscle has an excellent blood supply, and the overlying skin derives a significant proportion of its blood supply from the muscles by 'perforating' vessels passing through the deep fascia. Many muscles have only one or two nutrient arteries supplying the whole muscle. These arteries enter near either the muscle origin or the insertion, and this anatomical arrangement allows for the isolation of a muscle, with the overlying skin if appropriate, as a 'flap'. A vascular pedicle at one end of the muscle is carefully preserved, and the other end of the muscle is separated from its origin or its insertion. This allows the musculocutaneous flap to be rotated around a vascular pedicle in order to cover a tissue defect in an adjacent area.[5] The principles underlying flap surgery are discussed in more detail in Chapter 4A. Numerous adaptations of this principle have been developed in reconstructive surgery.

In managing sites that a standard flap will not reach, a free flap of muscle, with or without the overlying skin, is a possibility. The flap is detached completely and its nutrient artery and accompanying vein are anastomosed to suitable vessels in the recipient site using microvascular techniques.

Specific types of flap – such as the latissimus dorsi flap used in breast reconstruction and rectus abdominis, gracilis and pectoralis flaps – are discussed in the corresponding chapters of this book. Reconstructive flap surgery is the province of the plastic surgeon, but many general surgeons are experienced with the technique for the one or two flaps that are useful in their area of interest.

The gastrocnemius flap is useful in lower limb trauma. Tissue loss over a compound (open) fracture of the tibia is an injury that is slow to heal and prone to complications. The rotation of a musculocutaneous flap to cover the fracture site has proved very beneficial in this situation. For example, the medial head of gastrocnemius has a neurovascular bundle close to its origin. The muscle can be divided distally at the musculotendinous junction and swung medially to cover an exposed fracture of the upper tibia. The functional defect is compensated for by the other muscles in the flexor compartment. If a muscle flap is used without overlying skin, a split-skin graft can then be used to cover the muscle.

SOFT TISSUE MALIGNANCY

Malignant soft tissue tumours (sarcomas) are rare, and the diagnosis may be missed at initial presentation. These tumours metastasise via the bloodstream and not via the lymphatics. Treatment of the primary lesion must be through adequate wide excision, otherwise local recurrence is common, but no benefit is gained by lymph node dissection. The apparent 'capsule' of these sarcomata is merely a layer of compressed tumour cells and, therefore, 'marginal' excision in the natural plane just outside this capsule inevitably leaves a tumour bed that is contaminated with malignant cells. Surgical excision should therefore include a circumferential margin of normal tissue. When a sarcoma arises within a muscle, the excision should usually include the whole muscle or fascial compartment. Frequently, an initial excision has been undertaken for what was believed to be a benign lump, and a second more radical operation is indicated once there is confirmatory histology of malignancy. Limb amputation can usually be avoided. Radiotherapy may be an alternative to radical surgery in tumours that are highly radiosensitive. It is generally accepted that patients with these relatively rare tumours should be managed in centres with a special interest. An adequate biopsy and a staging computed tomography (CT) scan of the chest, abdomen and pelvis, as well as CT and/or magnetic resonance imaging (MRI) scan of the affected limb, are critical to plan optimal management of these rare tumours.

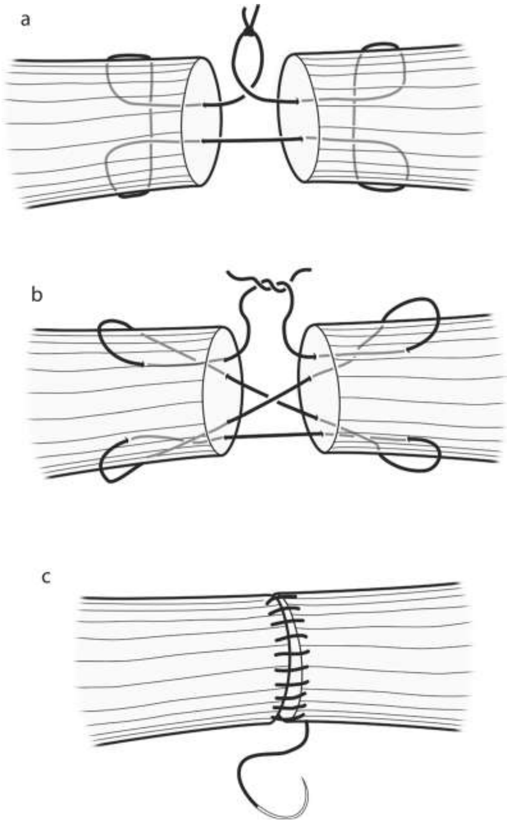
Pulmonary metastases are usually the first indication of metastatic spread, and occasionally surgical removal of isolated metastases in liver or lung can still offer the chance of a cure. Chemotherapy and radiotherapy have an increasing role, both in adjuvant and in palliative therapy.

TENDON REPAIR

A tendon is a condensation of fibrous tissue in continuity with a muscle. The origin of a muscle is commonly fleshy, from a wide area of bony cortex, but if a muscle arises from a localised area it may be tendinous, for example the common extensor tendon, arising from the lateral epicondyle of the humerus. The insertion of most muscles is tendinous, as the muscle is commonly inserted only into a localised area of bone. The tendon may be short in proportion to the muscle belly (e.g. the patella tendon) or long, such as in the tendons of the finger flexors and extensors.

A tendon may be severed by a laceration, and the long flexor and extensor tendons to the fingers are particularly vulnerable owing to their superficial position. Tendon rupture can also be caused by a blunt force. This may represent excessive force on a normal tendon or a minor strain on a degenerative tendon. A tendon may also disrupt at its attachment to bone or it may avulse the fragment of bony cortex to which it is attached. Rarely, a tendon may be avulsed from the muscle belly.

If no action is taken after tendon disruption, the muscle tone pulls the tendon ends apart. Any healing will be with a shortened muscle belly and an attenuated pseudo-tendon with a resultant diminution of function. Sometimes the ends can be approximated by extension, or flexion, of the relevant joint; an example of this is the use of relative motion splints for closed extensor tendon injuries of the hand.[6] For most tendon injuries, the results are better with a formal repair. The tendency for sutures to cut through the fibres is overcome by the techniques shown in Figure 21.8. However, the repair must be of adequate strength to overcome the forces channelled through the tendon. Suture configurations that result in at least four 'core' strands crossing the defect are now favoured (Figure 21.8b) and, for the large Achilles

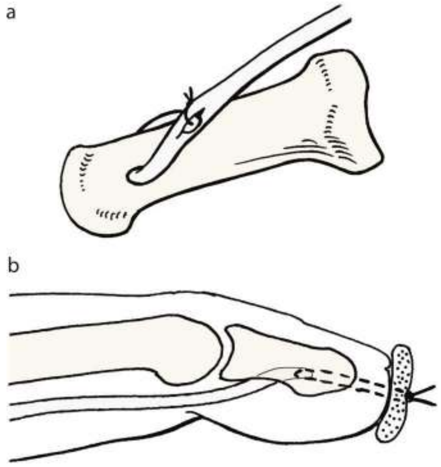


21.8 The propensity of a suture to cut through a tendon can be minimised by the locking loops that grip the outside of the tendon. (a) A classical method with two core strands – note the buried final knot. (b) A four-core suture configuration. (c) An additional finer continuous suture is inserted circumferentially in the epitendon. ⏎

tendon, a multistrand core suture is recommended. A continuous circumferential epitendinous suture then adds additional strength (Figure 21.8c).

Non-absorbable monofilament or multifilament sutures are recommended. If the tendon has severed at its bony attachment, tendon-to-bone fixation is required. This can be achieved with a suture anchor (a specially designed bone screw) or by simply drilling a hole through the bone and passing a suture through the hole. Two other methods are shown in Figure 21.9. A spontaneous rupture of a degenerative tendon can seldom be satisfactorily repaired, and the choices include acceptance of the disability, an attempt at a repair that will probably fail, or a tendon transfer or tendon graft operation. The palmaris longus and plantaris tendons are useful for grafting, as they are easy to harvest and have minimal donor morbidity.

Even after a tendon repair, splintage of the joint may be required to reduce tension during healing. However, prolonged immobilisation can lead to stiffness. An Achilles tendon rupture, treated surgically, has traditionally been managed with splintage of the ankle in plantar flexion for 6 weeks, but better results can be obtained by protected early mobilisation using a boot with heel wedges.



21.9 (a) The tendon has been passed through a hole drilled in the bone and sutured to itself. (b) A suture passed through the tendon and out through the terminal phalanx to the skin is tied over a button. After 3–4 weeks, the suture and the button are removed. ⏎

EXTENSOR TENDONS IN THE HAND

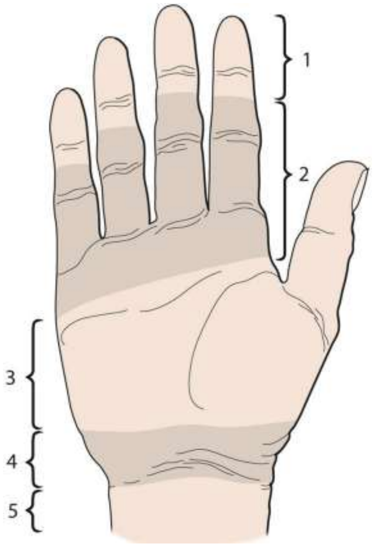
Extensor tendons in the hand heal well and may be repaired primarily by simple apposition. Some surgeons favour an absorbable suture, as it is impractical to bury a knot in these flat tendons. Avulsion of the extensor tendon from the base of the terminal or, less commonly, the middle phalanx of a finger can be successfully treated conservatively by splinting the affected joint in extension for 4–6 weeks.

EXTENSOR POLLICIS LONGUS

Repair of a spontaneous rupture of the extensor pollicis longus tendon is seldom practical. It may be ignored or a tendon transfer may be performed. Eric Farquharson, the original author of this textbook, had a spontaneous rupture of his extensor pollicis longus a few years before retirement. Within 2 weeks, he had adapted sufficiently to return to operative surgery – much earlier than would have been possible after a tendon transfer.

FLEXOR TENDON INJURY IN THE HAND

The current advice for managing a flexor tendon injury in the hand is that primary repair combined with early active motion rehabilitation under supervision offers better results than delayed grafting.[7] Early referral is



21.10 Primary repair of flexor tendons in zones 1, 3 and 5 is satisfactory, whereas repair in zone 2 and, to a lesser extent, in zone 4, is often disappointing owing to the formation of dense adhesions. ⏎

therefore indicated, if at all possible. Surgical repair can give disappointing results, even when undertaken by specialist surgeons. This is especially so in zone 2, where the tendons and their synovial sheaths are within the fibrous flexor sheaths (Figure 21.10); here, dense permanent adhesions commonly form during healing, especially if rigid splinting is employed. It is recommended that no repair is attempted when there is an isolated division of a superficial tendon within zone 2. If both flexor tendons are divided, only the profundus tendon should be repaired. Success with flexor tendon repair is dependent on the repair being strong enough to allow early protected movement. One of the key factors determining this strength is the number of core strands that cross the repair site. Various suture techniques have been described, but a four-strand core suture with a material such as 4/0 Ethibond™ is satisfactory (see Figure 21.8b). The epitendinous suture (e.g. with 6/0 nylon) not only adds 20% to the strength of the repair, but also improves gliding and reduces the incidence of gap formation, which is the initial event in repair failure. Tendon repairs are weakest between postoperative days 6 and 12, and the rupture rate can exceed 10%. After finger tendon repair, splintage to protect against excess force is required for 6–8 weeks.

Kleinert *et al.* (1967) reported that primary repair of zone 2 injuries had a good outcome if followed by early postoperative mobilisation with active extension and passive flexion in a 'lively' elastic band splint.[8] Meticulous postoperative care remains the key to a good functional outcome. Controlled mobilisation limits restrictive adhesions and improves tendon healing biology. Partial tendon lacerations of up to 50% can be treated by bevelling the laceration to prevent triggering. Early active movement is important, but heavy loads must be avoided for 6 weeks. Partial lacerations of over 50% should be repaired. Delayed presentation of flexor tendon injuries does not exclude primary repair if there is no segmental loss of the tendon, a good range of passive movement in the joints and no associated bony or soft tissue problems.

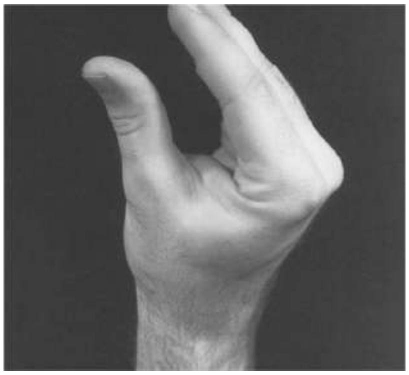
If the injury presents after more than 3 weeks, tendon grafting is the treatment of choice, because the muscle belly shortens and the tendon ends scar and form adhesions. Excision of the damaged tendons and grafting can be a single- or two-stage procedure. The fibrous flexor sheath may be excised, except for the major pulleys, which are left *in situ* to prevent bow stringing of the tendon graft. The superficialis tendon is excised and the profundus tendon excised from zone 2. The tendon graft is then carefully drawn through the pulleys. The two-tendon suture lines, to the distal profundus stump and to the proximal tendon in the palm, are thus outside zone 2, which is particularly prone to fibrosis. In chronic cases, there may be a fibrous contracture of the flexor digitorum superficialis (FDP) muscle belly and, in these cases, the flexor digitorum profundus (FDS) tendon from the ring or middle finger can be used as a tendon transfer, with a tendon graft.

INFECTIONS OF THE HANDS AND FEET

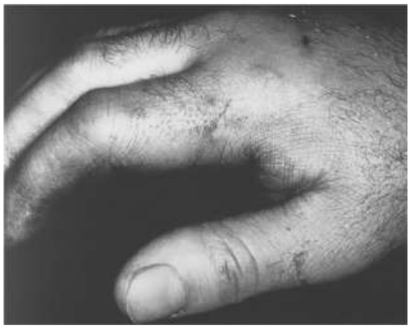
HAND INFECTIONS

Treatment is dominated by the need to prevent stiffness and the subsequent loss of function. The hand, whether injured by infection or trauma, is at high risk of a poor long-term functional outcome if restoration of mobility is delayed. Correct splintage combined with elevation to minimise swelling during the early phase, followed by intensive physiotherapy, is essential (Figures 21.11–21.13).

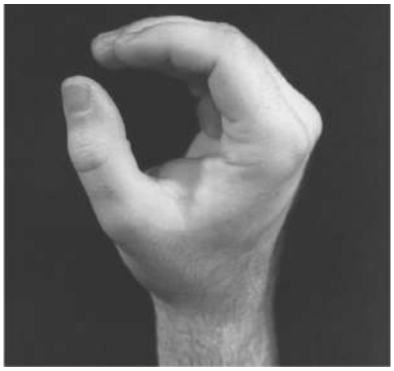
Early treatment of an infected hand with an appropriate antibiotic, and hand elevation, is often successful but, if rapid resolution does not occur, trapped pus must be suspected and released. It is not always immediately apparent in which compartment the pus is trapped, as the whole digit or hand will swell. Even the eventual 'pointing' may mislead if the anatomy is not appreciated (Figures 21.14 and 21.15). Samples should be taken for microbiology assessment of culture and sensitivities before starting antibiotics to guide subsequent treatment.



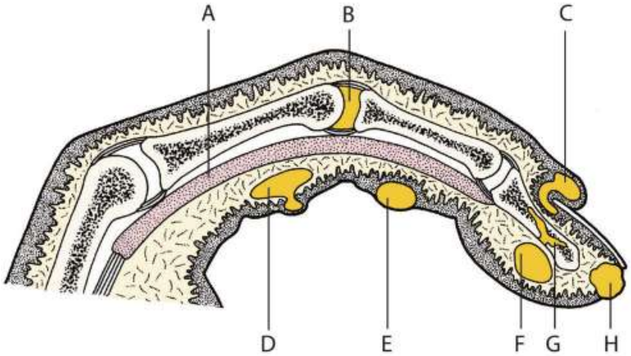
21.11 The ‘position of immobilisation’ for the hand. Relevant capsular structures are held at maximum length to prevent joint contractures. The wrist is slightly dorsiflexed, the interphalangeal joints are extended and the metacarpophalangeal joints are flexed. The thumb lies parallel to the fingers. ⏎



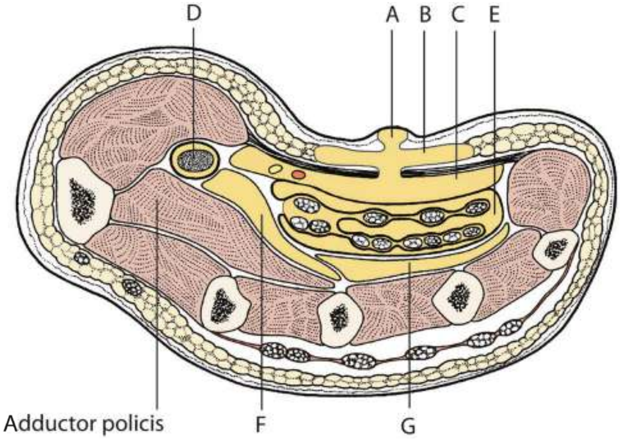
21.12 Injured joints seldom lie naturally in either the ‘position of immobilisation’ or the ‘position of function’. Injured hips and knees lie flexed and the injured hand adopts this position (see Figure 21.11). The hand must be elevated to reduce swelling and splinted in the correct position to prevent secondary contractures. ⏎



21.13 The ‘position of function’. A hand fixed in this position is still of functional use. This is not the correct position for immobilisation unless loss of joint movement is inevitable. ⏎



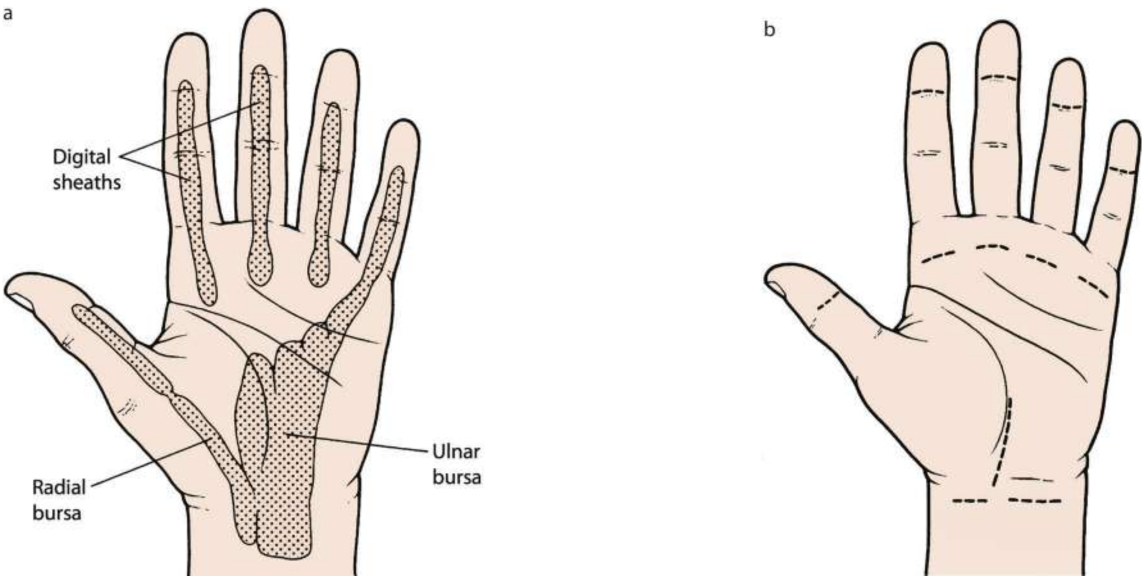
21.14 Infections that may affect a digit. A, tendon sheath infection; B, septic arthritis; C, paronychia; D, subcutaneous infection with a subcuticular ‘collar stud’ extension; E, subcuticular abscess; F, pulp space infection; G, osteomyelitis; H, apical pulp space infection. ⏎



21.15 The anatomy of hand infections, shown on a transverse section. A, subcuticular palmar abscess; B, subcutaneous palmar abscess; C, subaponeurotic palmar abscess; D, tendon sheath infection (radial bursa); E, tendon sheath infection (ulnar bursa); F, thenar space; G, deep mid-palmar space. ⏎

Synovial sheath infections

Infection within the synovial sheaths of the flexor tendons (Figure 21.16) can result in fibrous adhesions within the sheath or even sloughing of the tendon. The sheath should therefore be explored if pus is suspected or if complete resolution has not occurred within 48 hours of antibiotic treatment. Surgical exploration is carried out through two skin crease incisions – one placed over the proximal sheath and the other in the distal skin crease of the finger over the distal sheath. The sheath is drained and then irrigated with saline via a fine catheter, which can be left *in situ* for further irrigation over the ensuing 24–48 hours. It is better

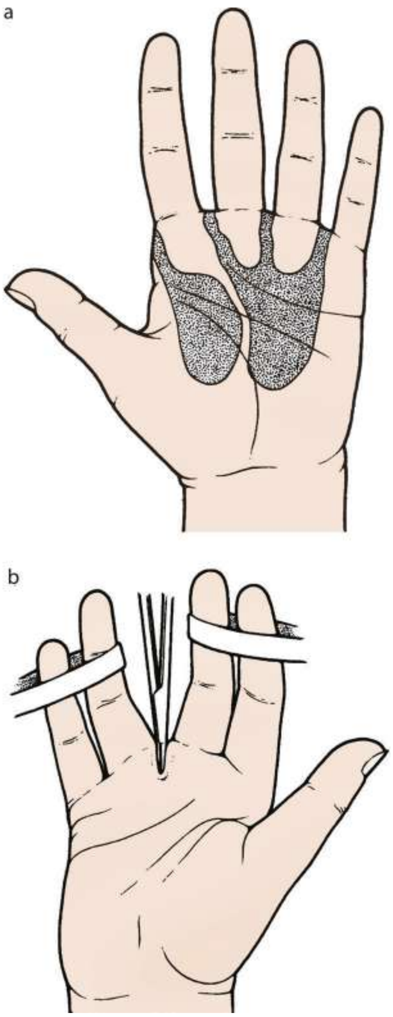


21.16 (a) The flexor tendon sheaths. (b) The incisions for drainage of tendon sheath infections. ⏎

to avoid extensive incisions, which expose the tendon, as these are difficult to close and risk necrosis if the tendon is left exposed.

Other soft tissue infections in the hand

Early diagnosis and antibiotic therapy have reduced the need for surgical intervention, but once pus has formed it should be drained. It should be remembered that deep pus may be difficult to diagnose if it fails to point superficially and that pus pointing superficially may be associated with a deeper collection that also requires drainage. For example, a *paronychia* may extend under the nail, necessitating nail avulsion for adequate drainage, while a *superficial septic blister* may connect with a deeper subcutaneous or pulp space collection. Between the palmar aponeurosis and the flexor tendons is the *superficial middle palmar space*. An infection of this space is usually caused by a penetrating wound of the palm; this presents as a 'collar stud' abscess in the palm (see Figure 21.15) and should be drained anteriorly. Neglected flexor sheath infections may lead to a 'horseshoe' abscess involving two or more flexor sheaths connecting through the mid-palmar space. This most commonly affects the thumb and little finger. Behind the flexor tendons are the *deep mid-palmar space* and the *thenar space*. Infection within these spaces is less common and initially presents with a generally swollen hand, this often being more noticeable on the dorsum. Drainage is undertaken from the web space, which is also where the pus will eventually point after tracking via the lumbrical canals (Figure 21.17).



21.17 (a) The thenar and deep mid-palmar spaces communicate with the web spaces via the lumbrical canals. (b) Drainage is via the web space. ⏎

FOOT INFECTIONS

In contrast with the hand, where the predominant concern is regarding stiffness and loss of function, infections in the feet carry a significant risk of loss of a limb. Penetrating trauma is common in the barefoot farm worker. The wound is contaminated by soil and then often neglected until there is established deep infection and even infected gangrene. Adequate drainage of pus is essential, combined with removal of dead tissue and contaminants. Culture of pus and tissue samples is useful, as infections may be polymicrobial and involve unusual organisms including fungal infections. Systemic antibiotics and repeated local treatment are continued until the infection has settled and healing has commenced. Only then should secondary suturing or reconstruction be considered. Amputation in the presence of infected gangrene is discussed in Chapter 20. In the developed world, most foot infections follow very minor trauma in diabetic patients. Diabetic neuropathy may have rendered the patient oblivious both to the trauma and to the early stages of infection. Impaired circulation, from both large vessel atheroma and diabetic microangiopathy, reduces tissue resistance, and the raised blood glucose provides an excellent environment for bacteria. Underlying pus must be considered if prompt resolution does not occur with appropriate antibiotics. Associated osteomyelitis of phalanges and metatarsal heads and septic arthritis may also occur early. Pus can be drained from a web space but often a ray amputation is required for a gangrenous toe or when additional bone or joint infection has become established (see also Chapter 20).

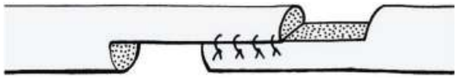
ELECTIVE TENDON SURGERY

TENOTOMY FOR ACCESS

A tendon may have to be divided to allow access for surgery. It is then repaired at the end of the procedure. Examples include tendon division, to allow full exposure of the popliteal artery for arterial reconstruction, and the tendon division necessary to enable transposition of the ulnar nerve to the flexor aspect of the elbow.

TENOTOMY AND TENDON LENGTHENING

Here, the techniques rely on the principle that natural healing of a divided tendon occurs with lengthening as the muscle tone distracts the cut ends. Whereas a simple tenotomy may be satisfactory in some circumstances, a formal tendon-lengthening procedure is superior when the muscle is functionally important (Figure 21.18). *Sternomastoid* tenotomy may be used to correct congenital torticollis. Division of the common extensor tendon from the lateral humeral epicondyle may be undertaken for an intractable '*tennis elbow*'. *Adductor*, *hamstring* and *Achilles* tendons can all be divided or lengthened to allow correction of a flexion deformity. Unfortunately, the tendon that is felt as the tight band restricting movement is often only part of the problem, and a further soft tissue release may be required. This is seen both in the treatment of congenital talipes equinovarus and in the *late contractures* after neglected trauma and paralysis that are so often encountered in areas with poor access to medical care. In some cases (e.g. the flexor muscles in the forearm), a fractional lengthening of the tendon at its origin from the muscle belly is possible. This allows more rapid healing and avoids the need for tendon suture. In the latter situation, there is often a fixed flexion of the hip and knee with an equinus ankle deformity. The surgeon is aiming for a plantigrade foot and a weight-bearing limb, with possible calliper support. Very careful assessment before surgery is essential. Shortened major vessels and nerves crossing the flexor aspect of the joint may still prevent extension. In addition, the correction of an equinus deformity may be counterproductive if it is compensating for a shortened limb.

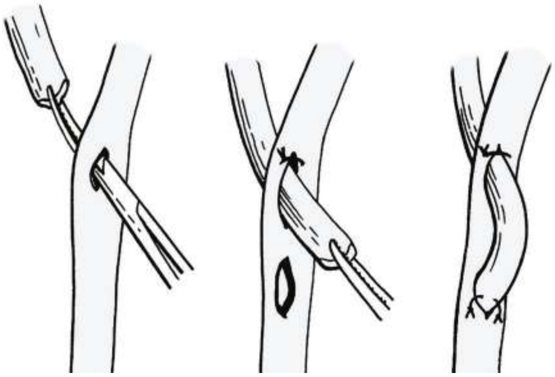


21.18 A tendon-lengthening technique suitable for a short Achilles tendon. ⏎

TENDON TRANSFERS

Tendon transfers are used to restore balanced active movement. Movement may have been lost as a result of muscle or tendon damage or there may be an imbalance from neurological disease. The muscle must be strong enough for its new role, with adequate amplitude of motion in a similar direction. It is also essential that the muscle can be spared from its original function. *Extensor indicis* fulfils these criteria when used to replace a ruptured *extensor pollicis longus*. Assessment is essential before embarking on surgery, and any fixed deformity must have been corrected. Tendons may be joined, as shown in Figure 21.19. The tension of the tendon transfer is critical to optimal function, and setting the tension slightly tighter than normal is usually ideal.

The *tibialis posterior* tendon may be transferred to correct the drop foot of paralysed peroneal muscles. The distal muscle and proximal tendon are mobilised above and behind the medial malleolus. The tendon



21.19 A technique for joining two tendons. ⏎

insertion into the navicula is divided through a separate incision. The tendon is transferred anteriorly and, through a separate incision over the base of the fifth metatarsal, is attached to the paralysed peroneus brevis. This is a useful technique for surgeons practising in countries with a high incidence of polio or leprosy.

TENDON GRAFTS

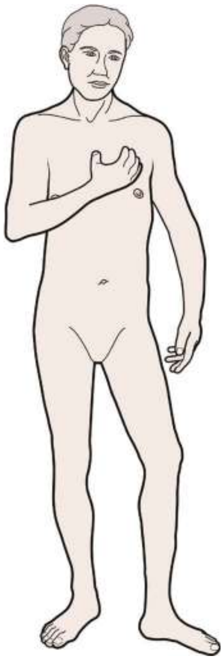
The non-essential tendons of the palmaris longus and plantaris can be used as grafts to bridge gaps in essential finger flexor tendons, as discussed above.

TENDON RELEASE

Stenosing tenosynovitis prevents free movement of a tendon within its sheath. In *trigger finger* or *thumb*, there is a nodular swelling on the flexor tendon that catches as it is pulled under the proximal end of the fibrous flexor sheath during extension of the digit. Surgical release is indicated if a period of non-operative treatment, which may include a steroid injection, fails. Surgery is performed through a short transverse or longitudinal incision, just distal to the distal transverse palmar skin crease; the neurovascular bundles must be protected. The extensor pollicis brevis and abductor pollicis longus may be trapped in separate tunnels within the first compartment of the extensor retinaculum at the wrist, and both tendons should be released. Care must be taken regarding the terminal branches of the radial nerve, as intractable pain can occur if they are damaged.

SURGERY OF LIGAMENTS AND JOINTS

Consideration must always be given to the position of any injured or inflamed joint, as even a healthy immobilised joint may stiffen. If a joint requires splintage, it should be immobilised in a position that holds the relevant capsular structures at their maximum length, rendering contractures less likely (see Figure 21.11). This is often a different position from that which the injured joint assumes naturally (see Figure 21.12). If long-term loss of movement and even bony ankylosis are inevitable, it is important that the joint is in the best position for any subsequent use of the damaged limb (Figure 21.20; see also Figure 21.13).



21.20 The 'position of function' in the lower limb is with the hip extended, the knee flexed to 10° only and the ankle dorsiflexed to 90°. Elbows fixed in acute flexion allow patients to feed themselves; extended elbows allow them to attend to toilet needs. When joint destruction is anticipated after an advanced septic arthritis or injury, splintage to obtain a joint position consistent with a functional limb is essential. ⏎

Ligaments are condensations of fibrous tissue on which the stability of a joint depends. Some, such as the cruciate ligaments of the knee and the ligament to the femoral head, are within the joint, and the latter also carries an important nutrient artery. More often they are outside the joint and are closely associated with the joint capsule. In traumatic rupture, the ligament itself may tear or it may avulse a fragment of bone from its insertion. Disruption of a ligament should be suspected if there is a haemarthrosis or if a small fragment of bone is seen on X-ray in the vicinity of a ligamentous insertion. Ligament disruption and instability of a joint are confirmed on stress X-rays, taken under local or general anaesthesia, to overcome the stability being maintained by the surrounding muscles.

REPAIR OF LIGAMENTS AND JOINTS

Immediate repair using similar techniques to tendon repair may be performed; however, in many cases, conservative treatment with a splint or plaster cast will allow satisfactory ligament healing, and the initial treatment is normally non-operative. When healing is unsatisfactory and the joint is unstable, a late reconstruction is undertaken. The ligament repair may need to be augmented with a tendon graft secured into a bone tunnel. This has proved especially effective for the anterior cruciate ligament of the knee and the ulnar collateral ligament of the thumb. These operations, however, are for experts in the field, and a non-specialist ‘occasional’ surgeon would expect poor results.

PYOGENIC ARTHRITIS

The management of joint infections often forms only a small part of the practice of a specialised orthopaedic surgeon, but in some areas of the world infections are common and a major cause of long-term disability. Urgent action is required to save the joint. Differential diagnosis from traumatic haemarthrosis, chondrocalcinosis and gouty arthritis may be obvious clinically, but if pus or blood is suspected, aspiration is essential to establish the diagnosis. A needle is introduced through an area of locally anaesthetised skin. If pus or blood is encountered, a wide-bore needle is required to ensure adequate drainage. Needle access to a swollen joint is normally straightforward, but consideration must be given to avoiding overlying vessels and nerves. The hip joint, however, can be more difficult, as it is deep and a joint effusion does not produce obvious swelling. A satisfactory method is to introduce the needle just above the tip of the greater trochanter and pass it upwards and medially, in the line of the femoral neck, until the joint is reached. (X-ray guidance is helpful if available.)

When all blood or pus has been evacuated, the joint is irrigated with normal saline. Septic arthritis requires high doses of antibiotics – preferably given intravenously – and repeat aspirations and irrigation should be performed daily until inflammation has settled. If the pus is thick and cannot be aspirated, the joint requires formal exploration for drainage. If available, arthroscopy is very helpful and avoids the need for a large arthrotomy. Consideration should be given to the best position for splintage (see above).

In a young child, if there is as yet no epiphyseal barrier to infection, septic arthritis may be associated with osteomyelitis. Failure to recognise and treat the additional pathology may have serious consequences (see Chapter 20).

ELECTIVE SURGERY OF JOINTS

Ganglia

These arise most commonly from the wrist and interphalangeal joints. Often, no surgery is indicated and some will disappear spontaneously as a result of rupture. This can be attempted therapeutically by aspiration of the contents with a wide-bore needle under local anaesthesia, followed by further disruption of the wall of the ganglion by multiple punctures with the same needle. If a ganglion is to be excised, it must be traced down to the joint capsule where, if there is a connection, it should be transected but left open. Adequate anaesthesia and a bloodless field are mandatory. Even if the excision is complete, recurrences are common.

Surgery within joints

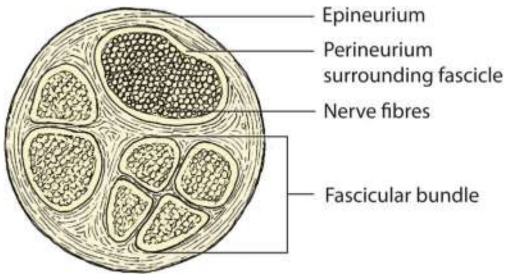
This includes reconstructive ligament surgery, trimming of meniscal tears, removal of loose bodies and synovectomies. Many open surgical procedures have been virtually replaced by minimally invasive techniques using an arthroscope. This is not surgery in which a general surgeon should be involved without additional orthopaedic training.

Arthrodesis and excision arthroplasty

Ankylosis, or spontaneous bony union, may develop across a joint that has been severely injured by trauma or infection. Ankylosis may give a good functional result if fusion occurs in the position of function. *Arthrodesis*, in which a joint is surgically excised, inducing bony union, is based on the same principle. A severely diseased, painful joint may be excised as an *excision arthroplasty*, in which the aim is to obtain a fibrous rather than a bony union. These procedures are discussed briefly in Chapter 20, as they may be of value to the isolated generalist.

Joint replacement

This is now a standard technique for hip, knee and shoulder joints badly damaged by degenerative and other pathologies. Other joint replacements are performed less frequently. Orthopaedic operative texts cover this enlarging field.[1]



21.21 Diagrammatic cross-section of a peripheral nerve. ⏎

NERVE INJURIES

A major peripheral nerve is made up of a large number of fibres; for example, there are over 10,000 in the median nerve in the forearm. Each fibre consists of an *axon* surrounded by its Schwann cell sheath. The axon is the process of a nerve cell, the main body of which lies within the dorsal root ganglion or within the central nervous system. The peripheral nerves carry, to a varying degree, fibres concerned with motor, sensory and autonomic functions. Groups of nerve fibres are aggregated into bundles, or fascicles, which are surrounded by a thin layer of connective tissue. There is a strong and distinct layer of connective tissue, the *epineurium*, which surrounds the fascicles that make up a nerve trunk (Figure 21.21). The connective tissues of a peripheral nerve are surprisingly strong so it is not uncommon to find the major nerves as the only intact structures in a severely injured limb. The peripheral nerves are supplied by many small arteries, which communicate freely within the nerve. It is possible, therefore, to mobilise quite long lengths of nerve without damaging the blood supply.

Nerve injuries may be divided into three degrees of severity:

1. In *neurapraxia*, the axons are not disrupted, but nerve conductivity is temporarily lost. Recovery occurs spontaneously within hours or days of the injury.
2. In *axonotmesis*, the axon is disrupted but the supportive connective tissues of the nerve remain in continuity. The axon has to regrow along the intact sheath and there is no functional recovery until it reaches the end organ. The growth rate is around 1 mm a day.
3. In *neurotmesis*, the nerve is completely divided. No recovery occurs unless surgical repair is undertaken as the ends retract, the axonal outgrowths fail to find an axonal sheath and scar tissue forms.

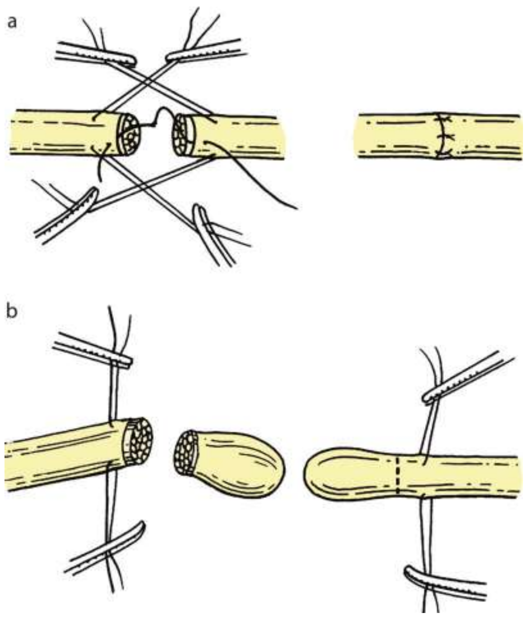
Surgical repair is an attempt to convert a neurotmesis into a situation similar to an axonotmesis, but the result is never as good, as many axons still fail to grow down a sheath. In addition, sensory regrowth towards a motor end plate, and vice versa, is of no functional benefit.

NERVE REPAIR

A loss of nerve function in a *closed injury* is usually either a neurapraxia or an axonotmesis, and the initial management can be conservative. If recovery does not occur within a few days, the injury is probably an axonotmesis and there will be a long wait as the axons regrow. However, the possibility that the nerve is divided should be considered, even in a blunt injury. If doubt continues, surgical exploration should be considered. The integrity of a nerve in the vicinity of any *open injury* should be checked and a loss of nerve function distal to a wound always suggests a divided nerve. When the wound is explored, the severed nerve ends are identified and a decision is then made as to whether to proceed with a primary nerve repair. A bloodless field with a tourniquet provides the best conditions for nerve repair, but a tourniquet may be contraindicated in an extensively damaged limb in which additional ischaemic insult should be avoided. Primary repair may be the best option, but only in clean, incised wounds of limited extent and where surgeons have the necessary experience, instruments and time at their disposal. Therefore, most general surgeons will wish to enlist the help of an orthopaedic or plastic surgical colleague with special expertise and, if not available, to opt for secondary repair. An isolated general surgeon may have limited experience, combined with a lack of fine equipment, but, if referral is impractical, will have to proceed with either primary or secondary repair.

If repair is to be delayed, the nerve ends should be prevented from retracting. If the ends can be approximated without tension, they can be apposed with two or three inert sutures to await a more formal repair. Correct orientation at this stage may be easier than subsequently, and should be attempted and documented. If the severed ends cannot be apposed, they can be marked with a fine non-absorbable suture to facilitate future identification. Delayed repair will often require the use of a nerve graft to avoid tension.

Nerve repair, if at all possible, should be performed with the help of some form of magnification, either loupes or an operating microscope, to prevent further damage to the nerve by clumsy dissection and to ensure accurate orientation of the nerve and placement of sutures. Sutures should be of a relatively inert material, such as nylon or Prolene™, and should be very fine (8/0 or finer). Silk and absorbable sutures provoke an inflammatory response and should not be used.



21.22 Nerve repair is by epineural sutures, and correct orientation of nerve bundles is essential. (a) The initial guide sutures hold the orientation and prevent inadvertent subsequent rotation of one end. They can also be used to rotate both ends of the nerve together so that the posterior sutures can be inserted. (b) In secondary repair, the neuroma must first be excised. ⏎

Primary repair

For primary suturing, only minimal trimming of the nerve ends is required. This is carried out with a sharp blade with the nerve resting on a firm surface. Correct orientation of the nerve is facilitated by noting the arrangement of the fascicular bundles within the nerve (see Figure 21.21) and the presence of any blood vessels on the surface. Intraneural dissection, and sutures, cause further fibrosis and should be avoided; the repair is with epineural sutures. The first two sutures may be left long and held to steady and rotate the nerve; alternatively, initial 'guide sutures' can be placed as illustrated in Figure 21.22. Excessive suturing should be avoided. For example, six to eight sutures are sufficient for the median nerve, and two to three sutures are sufficient for a digital nerve.

Secondary repair

At a secondary repair, it is safer first to identify the nerve, both proximal and distal to the scar tissue, and only then to dissect the injured site. If the ends have been aligned at the original exploration, guide sutures placed before excising the bridge of neuroma and scar tissue will facilitate maintaining correct alignment; in addition, these sutures can be used to draw the ends together. Both ends must be cut back to undamaged nerve beyond the scar tissue and the neuroma (Figure 21.22b). This is recognised when the nerve bundles pout separately from the cut surface and may require up to 1 cm of excision. Orientation, alignment and suturing are carried out as for a primary repair. The epineurium is thicker than in a primary repair and suturing is easier. Mobilisation of the ends will be required to achieve apposition without tension, but, if the defect is greater than 2–3 cm, direct suturing is not possible without shortening the course of the nerve by transposition or by flexion of a joint. A nerve that is relatively redundant for normal function, such as the sural or saphenous, is used as a graft to bridge the gap. Techniques for nerve grafting and for the repair of partially severed nerves are for specialists with expertise in the field and will give disappointing results when used by generalists.

After any nerve repair, immobilisation is indicated for 3 weeks to protect the suture line from tension. Flexion of a joint may be required to prevent initial tension on a shortened nerve, but marked flexion should be avoided by the use of nerve grafts. Subsequent extension of the joint must be a controlled slow increase over several weeks to prevent disruption of the repair. While awaiting axonal regrowth, whether after axonotmesis or nerve repair, the patient must be shown how to use passive movements to retain joint mobility. Advice must also be given to minimise the risk of accidental injury to skin that has no protective sensation. Splintage to maintain function and prevent contractures may also be needed during the recovery period.

Good functional recovery is dependent not only on the technical success of the repair but also on the distance that the axons have to grow to reach the end plates and on whether the nerve is mixed or mainly either sensory or motor. Therefore, the technical challenges and the functional results of the repair of different nerves vary.

Facial nerve The facial nerve may be damaged or intentionally sacrificed for oncological reasons during parotid surgery. Direct apposition is seldom possible, but good results can be achieved with nerve grafts. If this is unsuccessful, management can be with dynamic muscle transfer. Neurapraxia after a superficial parotidectomy is not uncommon, but if the surgeon is confident that all branches of the nerve were identified and preserved, there can be reasonable confidence that function will recover, commonly within a day or two if there has been no axonal disruption (see also Chapters 4B and 23).

Recurrent laryngeal nerve The recurrent laryngeal nerve may be injured in thyroid surgery (see also Chapter 23). Neurapraxia will recover, but a severed nerve causes permanent cord paralysis, with a resultant deepening and reduced force to the voice. A bilateral injury results in both cords drifting medially. A tracheotomy may have to be performed to maintain the airway. Any form of nerve reconstruction is very difficult.

Brachial plexus Injury to the brachial plexus is most often seen after motor cycle accidents and is caused by a severe traction force that may also have damaged the proximal subclavian artery. The injury is often of mixed severity, with some portions of the brachial plexus suffering only neurapraxia, while other portions have axonal disruption or are completely severed. The prognosis is therefore very varied. Surgical repair of a severed nerve may not be practical, as the most common site of damage is an avulsion of the roots from the spinal cord. Some surgeons advocate early exploration, but, as access is difficult and often little can be achieved in the way of a repair, this is unlikely to appeal to the generalist who, with limited experience of the problem, is in danger of causing more harm than good. Patients should be referred for a specialist opinion if this is available. Obstetric brachial plexus palsy, associated with shoulder dystocia during delivery and presenting in the neonatal period, will often resolve spontaneously.

Radial nerve The radial nerve is vulnerable to damage from the bone ends in a humeral shaft fracture. In most cases, the nerve will recover with non-operative treatment. Repair of the nerve will usually produce good results, as it is mainly a motor nerve. The distance to the end plates, however, delays recovery for 3–4 months and a splint for wrist drop is required. If the nerve repair is unsuccessful, the wrist drop can be treated by tendon transfer.

Median nerve The median nerve is most often divided in a laceration of the wrist or forearm. The radial or ulnar artery may also have been divided and additional tendon damage is also common. At the wrist, the median nerve is flattened and easily mistaken for a tendon. It is therefore important that exploration, as well as repair, is undertaken under optimum conditions; this requires a bloodless field with a tourniquet. Postoperative flexion of the elbow reduces tension on a median nerve repair at the wrist and is preferable to palmar flexion of the wrist. If the wrist is held in acute flexion during healing, the adherence of the nerve at the site of injury to adjacent tissues can cause traction problems when the wrist is mobilised.

Ulnar nerve The ulnar nerve may be divided at the wrist, where the challenges in diagnosis and successful repair are similar to those encountered in median nerve damage. If the ulnar nerve is severed at the elbow, it is advisable to bring the divided ends anteriorly for a tension-free repair. Anterior translocation of an intact ulnar nerve is described below.

Sciatic nerve Repair of the sciatic nerve, although technically straightforward, gives poor functional results.

Autonomic nerves Repair of autonomic nerves is not a surgical option, as these nerves consist of non-myelinated nerve fibres; effective axonal regrowth is not possible in the absence of axonal sheaths, even if the ends are approximated. Pelvic surgery endangers both the sympathetic and the parasympathetic nerves to the bladder and sexual organs, and great care must be taken to cause the minimum amount of damage.

Nerve infections In the early stages of a *herpes zoster* infection (shingles), the dermatome pain precedes the skin rash and can cause major diagnostic confusion. *Poliomyelitis* presents to the surgeon after the acute illness with residual limb paralysis and deformity. The nerve infections in *leprosy* also lead to paralysis and deformity but, in addition, the loss of sensation results in distal soft tissue damage. The surgical implications of polio and leprosy are substantial, but the surgery required is not on the nerves themselves.

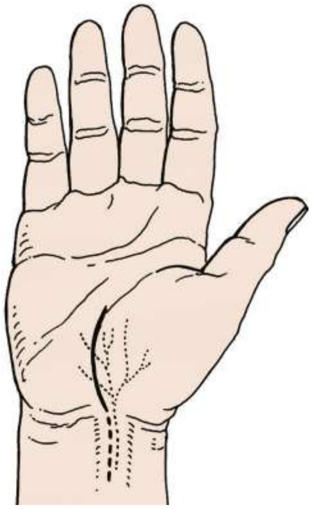
ELECTIVE SURGERY OF NERVES

NERVE RELEASE

Nerve release is indicated if a nerve is suffering repeated trauma or constriction resulting in an 'entrapment' neuropathy. The neuropathy may take the form of pain, altered sensation or muscle weakness and wasting. Conservative measures include rest and/or local steroid injection to reduce local inflammatory swelling, but surgical release is still often indicated. It should not be delayed until irreversible damage to the nerve has occurred.

Carpal tunnel release

This procedure is indicated when conservative management has failed to relieve median nerve compression. If there are signs of neuropathy, permanent sensory changes and thenar wasting, early surgery should be considered, although the prognosis is less good. The operation is normally performed under local anaesthesia. The incision (Figure 21.23) is deepened through the palmar fascia to expose the flexor retinaculum. The flexor retinaculum must be divided completely to release the median nerve, and the proximal edge of the retinaculum must be sought under the skin if the skin incision stops short of the wrist crease. The thenar motor branch is at risk, and an incision to the ulnar side of the nerve is safer than directly over it. Only the skin is sutured.



21.23 The incision for carpal tunnel decompression is placed slightly towards the ulnar side of the midline to avoid the palmar cutaneous branches of the median nerve. The skin incision can stop short of the wrist crease. ⏎

Ulnar nerve decompression

Ulnar nerve decompression, *in situ* in the cubital tunnel, will usually relieve entrapment symptoms. Transposition to the front of the elbow shortens the course of the nerve and reduces tension, but is a more complex procedure, as the common flexor tendon has to be divided and then repaired after the ulnar nerve has been transposed. Additionally, to ensure sound healing of the tendon, the elbow should be immobilised for 3 weeks.

Lateral cutaneous nerve

The lateral cutaneous nerve of the thigh may be trapped under the inguinal ligament, and symptoms usually settle with steroid injections.

Thoracic outlet syndrome

Thoracic outlet syndrome is a rare condition that presents with a mixed pattern of nerve and arterial compression. A prominent first rib, or an accessory cervical rib, causes trauma predominantly to the axillary artery and the C8 and T1 nerve roots, whereas prominent scalene bands may traumatise C5 and C6. The place of surgery in this condition, and the operative options, are discussed in Chapter 19.

Intercostal nerves

Intercostal nerves may be trapped as they emerge from under the costal margin, but more commonly the entrapment occurs as they enter the rectus sheath. Surgical release is seldom indicated, as symptoms usually settle with steroid injections, but they can present diagnostic problems.

NERVE DIVISION AND ABLATION

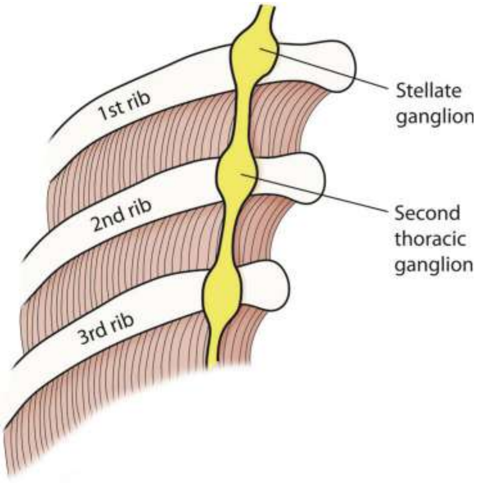
Intentional surgical division of nerves is now restricted to vagotomies and sympathectomies. Historically, *phrenic* nerve-crushing techniques were used to cause an axonotmesis. The diaphragm was paralysed, and 'rest' of the tuberculous lung was believed to encourage healing. As the axons regrew the function recovered.

Vagotomies

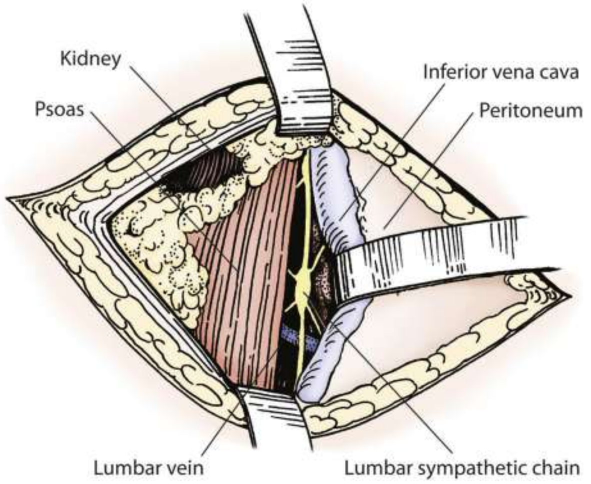
Truncal, *selective* and *highly selective vagotomies* are discussed in Chapter 8.

Cervical sympathectomy

Cervical sympathectomy is the somewhat misleading misnomer for the operation performed on the upper thoracic sympathetic chain to obliterate sympathetic innervation to the upper limb. (The inferior cervical ganglion, which may be fused to the first thoracic ganglion as the composite stellate ganglion, is in fact carefully preserved to prevent Horner's syndrome.) The operation has a declining role in the management of vasospastic disorders, but has proved valuable in the treatment of hyperhidrosis. It is now almost exclusively performed by video-assisted thoracoscopic surgery (VATS), and a two-port transaxillary approach is usually satisfactory, although a single operating port is also popular. A double-lumen endotracheal tube is required to allow one lung to be deflated (see also Chapter 22). The upper thoracic sympathetic chain is identified as a pale pink structure crossing the necks of the ribs. It is deep to the parietal pleura, which must be incised to isolate it (Figure 21.24). The stellate ganglion normally lies on the neck of the first rib and the outflow to the upper limb is below this, from the second to the fifth thoracic ganglia. Cervical



21.24 The sympathetic chain lies on the neck of the ribs. ⏎



21.25 The lumbar sympathetic trunk lies in the groove between the psoas muscle and the vertebral bodies. On the right, the inferior vena cava may overlap it and must be gently retracted. ⏎

sympathectomy consists of division of the sympathetic chain below the neck of the second rib and destruction of the second thoracic ganglion. This is the standard operation for palmar hyperhidrosis. The techniques of individual surgeons vary and there is still controversy about whether a resection or an ablation technique is superior.[9] If repeat surgery is indicated after initial failure of this operation, a T3 sympathectomy is performed and the lower half of the stellate ganglion may also be sacrificed. Any damage to the upper portion of this ganglion will result in Horner's syndrome. Control of axillary hyperhidrosis requires a T2/T3 sympathectomy, while extension to a T4 sympathectomy may be indicated if repeat surgery is required. Destruction of sympathetic innervation often results in troublesome compensatory sweating.[10] Many surgeons prefer to offer subdermal Botox injections for axillary symptoms. This is a more effective treatment with considerably less risk, but the benefits only last for approximately 6–12 months. Repeat treatments produce a diminishing return over 4 or 5 years.

Lumbar sympathectomy

Lumbar sympathectomy plays a limited role in increasing skin perfusion and, although there is little evidence that it can reverse any of the effects of arterial disease, it occasionally has a role to play in pain control for patients with no options for revascularisation. Similarly, it has been employed for lower limb vasospastic disorders, accepting a very limited evidence base. Lumbar sympathectomy is now most often achieved with a chemical ablation of the sympathetic chain by a paravertebral injection under radiological control. The alternative surgical sympathectomy is performed through a retroperitoneal approach via an oblique loin incision. The sympathetic chain is found lying in the groove between the vertebral bodies and the psoas muscle. On the right it is behind the inferior vena cava (Figure 21.25) and on the left it is beside the left margin of the aorta. The first lumbar ganglion is high up under the crus of the diaphragm and the fourth may be obscured by the common iliac vessels. Removal of the second and third ganglia obliterates the sympathetic innervation distal to the mid-thigh and is normally sufficient. If the first lumbar ganglion is destroyed bilaterally, ejaculatory failure will be inevitable.

Splanchnicectomy

Bilateral thoracoscopic splanchnicectomy has been employed for the relief of pain in chronic pancreatitis, but gives sustained long-term relief in only a minority of patients.[11] The sympathetic chains are exposed from the level of the T5–T12 ganglia and their splanchnic branches are divided.

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Cardiothoracic surgery for the general surgeon

22

Sanjeeth Peter

INTRODUCTION

There have been many advances in almost every aspect of surgical treatment, ranging from case selection and preparation to technical advances in surgical technology and enhancements in postoperative care. Parallel to this has been optimisation of patient comorbidities and advances in anaesthesia. The availability of quality surgical treatment has also become more widespread, and speciality surgical procedures are now offered in many medical establishments and often in units with suboptimal facilities. Nevertheless, the availability of facilities that offer specialist surgical care remains unequally distributed. Cardiothoracic surgery, a speciality dealing with the chest (including the chest wall [ribs, pleura] and structures inside the chest), lungs, trachea, bronchi, pericardium, heart, great vessels and structures above the diaphragm, continues to be mainly available in larger cities and hospitals all over the world. As a result, large geographical areas are still underserved by cardiothoracic expertise, and referrals to specialised units are the norm. When transport facilities are incapable of caring for critically unwell patients, the well-being of the patient in remote areas remains precarious and often a matter of destiny.

Due to the extent and nature of cardiothoracic disease, and the distances to cardiothoracic units, a general surgeon is often called upon to intervene and initiate treatment. Sometimes, a simple procedure such as a chest tube insertion to drain a haemothorax or parapneumonic effusion can prevent a serious complication, and timely intervention can be life saving in a patient with a tension pneumothorax. In some situations, when speciality surgical care is available at a distance, the general surgeon will be called upon to stabilise the patient prior to transfer, especially in trauma. When the condition is life threatening, and the treatment does not involve sophisticated instruments and gadgets, it is the training, and the initiative, of the surgeon available on the ground that can decide the fate of the patient.

Cardiothoracic surgery is becoming further specialised into adult and paediatric surgery with subspecialisation into valvular, coronary, great vessels and thoracic non-cardiac. In this scenario, the exposure to cardiothoracic surgery during an elective posting of a general surgical trainee may not be adequate to prepare the surgeon for cardiothoracic surgical emergencies or even life-saving elective procedures. In the resource-limited setting, the general surgeon will need to venture into those surgical treatments in a life-threatening situation or when there is no specialist available. The surgery could range from a chest tube insertion to a pericardiostomy.

It is of paramount importance for the general surgeon to prepare for their role in a resource-limited setting or a remote hospital. Perhaps a short stint in a busy thoracic unit can be explored, but a list of all the nearby speciality centres and having a network of surgeons who can offer advice, even over the telephone or via video call, can be of immense help.

Many small, remote hospitals have unexpected, and unused, equipment and instruments. It is advisable for a surgeon to meticulously explore and take note of all such instruments and equipment on appointment to a job. An instrument used in a different speciality may be useful and be repurposed for an entirely different operation. A Hegar dilator, which is commonly used in gynaecological procedures, is a great instrument to temporarily plug bleeding from a large vessel such as the aorta, giving precious time to prepare for repair.

Faced with a situation in which a surgeon needs to step out of their comfort zone and operate, the surgeon needs to know the universal ‘language of a surgeon’. The language involves possessing adequate knowledge of anatomy and being familiar with the surgical approaches for the condition, the steps of the procedure and key postoperative care. In addition, it is useful to keep in mind what is likely to be problematic, what can go wrong, how best to avoid complications and, if complications occur, how best to tackle them. ‘First do no harm’ is a prerequisite.

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This chapter follows the universal language of a surgeon and will be presented in the following manner:

- Essential anatomy
- Functioning of the chest
- Surgical access to navigate inside the chest
  - Posterolateral thoracotomy
  - Anterolateral thoracotomy and clamshell thoracotomy
  - Lateral thoracotomy
  - Sternotomy
  - Cervical approach
  - Transclavicular approach
  - Transhiatal approach
  - Video-assisted thoracoscopic surgery (VATS)
- Procedures for a general surgeon
  - Thoracic procedures
    - Chest tube insertion
    - Thoracotomy for pleural drainage
    - Decortication
    - Pleurodesis
    - Lobectomy
    - Mediastinal tumour excision
  - Chest trauma
    - Rib fractures/Chest wall stabilisation
    - Flail chest
    - Sternal fractures
    - Injury to the great vessels and heart
    - Oesophageal injury
  - Surgery on the heart and great vessels
    - Pericardiostomy
    - Pericardiectomy
    - Blalock–Taussig shunt
    - Surgery for coarctation of the aorta
    - Surgical closure of a patent ductus arteriosus

It is important to emphasise again that one has to be prepared at all times to deal with a situation requiring skills in thoracic surgery. Therefore, continuing to familiarise yourself with the materials that are easily available is a good strategy. Decisions must also be based on the competence of the surgeon, remembering that attempting a heroic surgical procedure can cause more damage when not performed well and seeking appropriate help enhances the chances of a good outcome. It is always good practice to step back for a moment and ensure that the surgical procedure that you are embarking on is really the best option under the circumstances.

ESSENTIAL ANATOMY

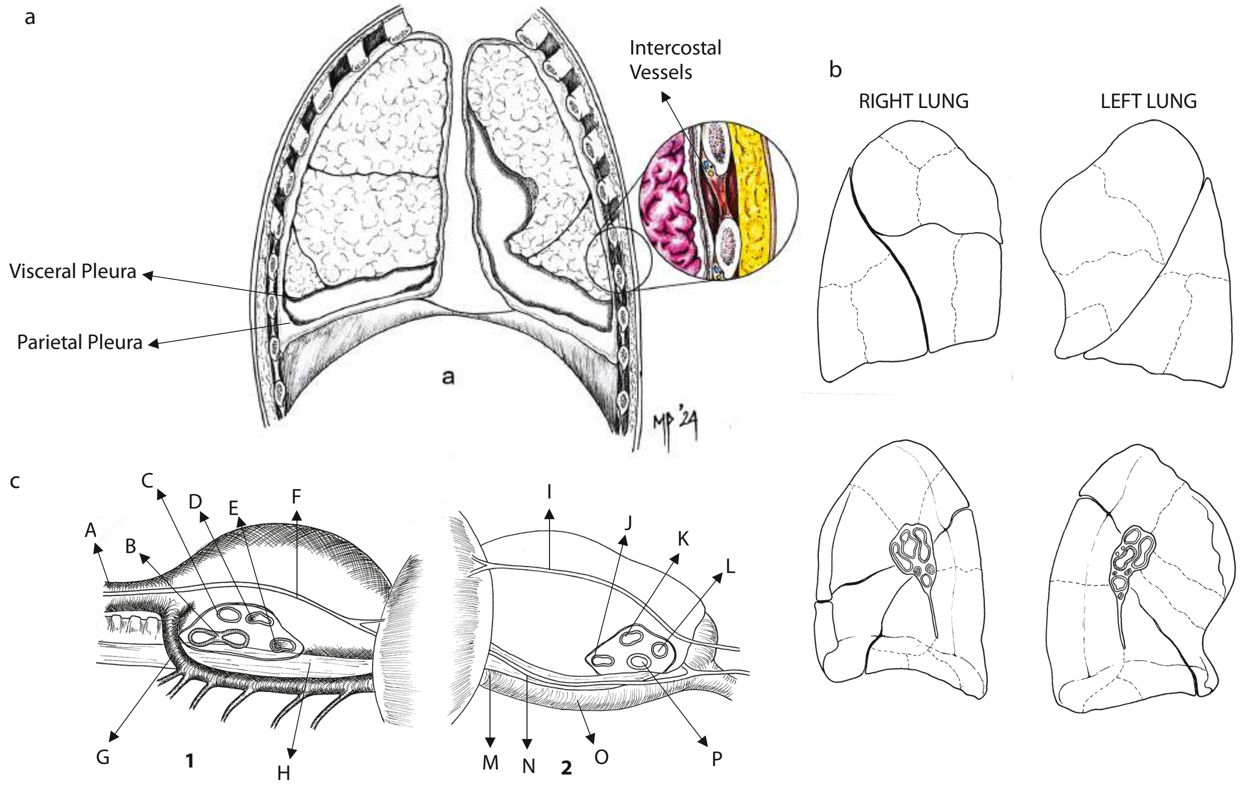
A knowledge of the anatomy of the chest, and its contents and structure, are essential for successful intervention. The chest can be studied in three portions: the chest wall, the pleural cavity and the mediastinum. The chest wall comprises the ribs with the intercostal muscles. Although flat, the inferior margins of the ribs are notched, where the intercostal vessels and nerve traverse from posterior to anterior (Figure 22.1a). Ribs are attached to each other by intercostal muscles that are attached obliquely to permit expansion of intercostal spaces during respiration. The inner lining of the chest wall is the parietal pleura. Much like the visceral peritoneum lines the intestines and the parietal peritoneum lines the abdominal wall, the visceral pleura lines the lungs and the parietal pleura lines the chest wall. Thickening of the parietal pleura hampers intercostal space expansion (it is important to note this, as this layer also must be removed in decortication surgery).

The hilum is the attachment of the lungs to the mediastinum. The bronchi, pulmonary artery and pulmonary veins comprise the hilum (Figure 22.1b). The pleural space (between the parietal and visceral pleura) is a cavity where blood, other fluid or air can collect, reducing the space for lung expansion.

The mediastinum is bound on either side by the mediastinal parietal pleura, superiorly by the thoracic outlet and inferiorly by the diaphragm. Structures within the mediastinum are the thymus, retrosternal goitre, heart, great vessels, trachea and bronchi (Figure 22.1c).

FUNCTIONING OF THE CHEST

Knowledge of the functioning of the chest cavity is fundamental to approaching operations in this anatomical area. Unlike any other cavity, chest cavity functioning is directly dependent on atmospheric pressure. To ensure the lung remains expanded, the pleural cavity has to be intact. Opening of the chest cavity will result in the immediate collapse of the lung. The only way that the lungs can remain expanded when the pleural cavity is breached is by positive pressure ventilation. While this can easily be achieved by endotracheal intubation, when surgery has to be performed in one of the pleural cavities, the expanded lung does not allow space to operate. Adequate space, and an unobstructed view, can be achieved if the lung is allowed to collapse while maintaining ventilation through the other lung. In order to control the expansion of the lungs separately and isolate the lungs from each other, a double-lumen tube is used (Figure 22.2a). Although convenient to use, the placement of these tubes is of utmost importance. The use of a video-assisted laryngoscopy is likely to improve the chances of better placement in the trachea; however, bronchial placement also needs to be accurate, especially on the right side, where the right upper lobe



22.1 (a) Sagittal section of thoracic wall. Note the intercostal vessels in the inferior groove of the rib. (b) Lungs: right lung with three lobes and nine segments and left lung with two lobes and eight segments. (c) (1) Right hilum. (2) Left hilum. A, superior vena cava; B, right bronchus; C, right pulmonary artery; D, right superior pulmonary vein; E, right inferior pulmonary vein; F, phrenic nerve; G, azygos vein; H, oesophagus phrenic nerve; J, left inferior pulmonary vein; K, left superior pulmonary vein; L, left pulmonary artery; M, oesophagus; N, vagus nerve; O, aorta; P, left bronchus. (Illustrated by Mahil Matthew Peter.) ⏎

bronchus is just after the origin of the right main bronchus (Figure 22.2b). Anaesthesiologists sometimes use the left-sided double-lumen tube (Figure 22.2c) in all cases, as accurate placement of the right tube to ensure alignment with the right upper lobe bronchus is especially difficult if a fibreoptic bronchoscope is not available.

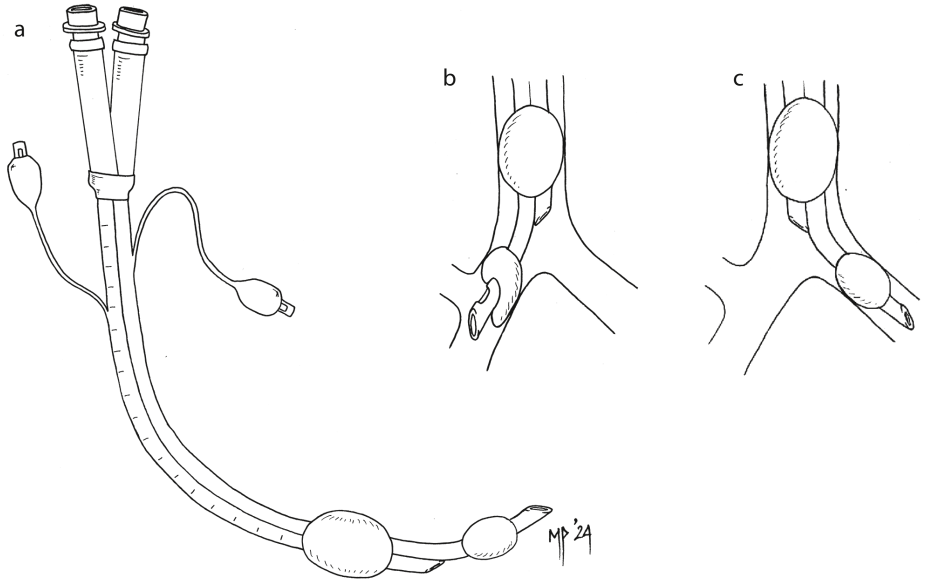
Other methods have been described for lung isolation, such as using single lumen tubes with bronchial occluders. The principle is to isolate ventilation to one lung. This has the dual advantage of isolating the airway for ventilation and preventing spillage from the involved bronchus into the uninvolved bronchus, as these thoracic surgeries are performed with the patient in the lateral position with the unaffected side in the dependent position. Single lung anaesthesia, being unphysiological, carries with it the risk of postoperative pulmonary complications, which can be reduced by skilful anaesthesia involving lung protective ventilation with moderate levels of positive end-expiratory pressure (PEEP).[1,2]

SURGICAL ACCESS

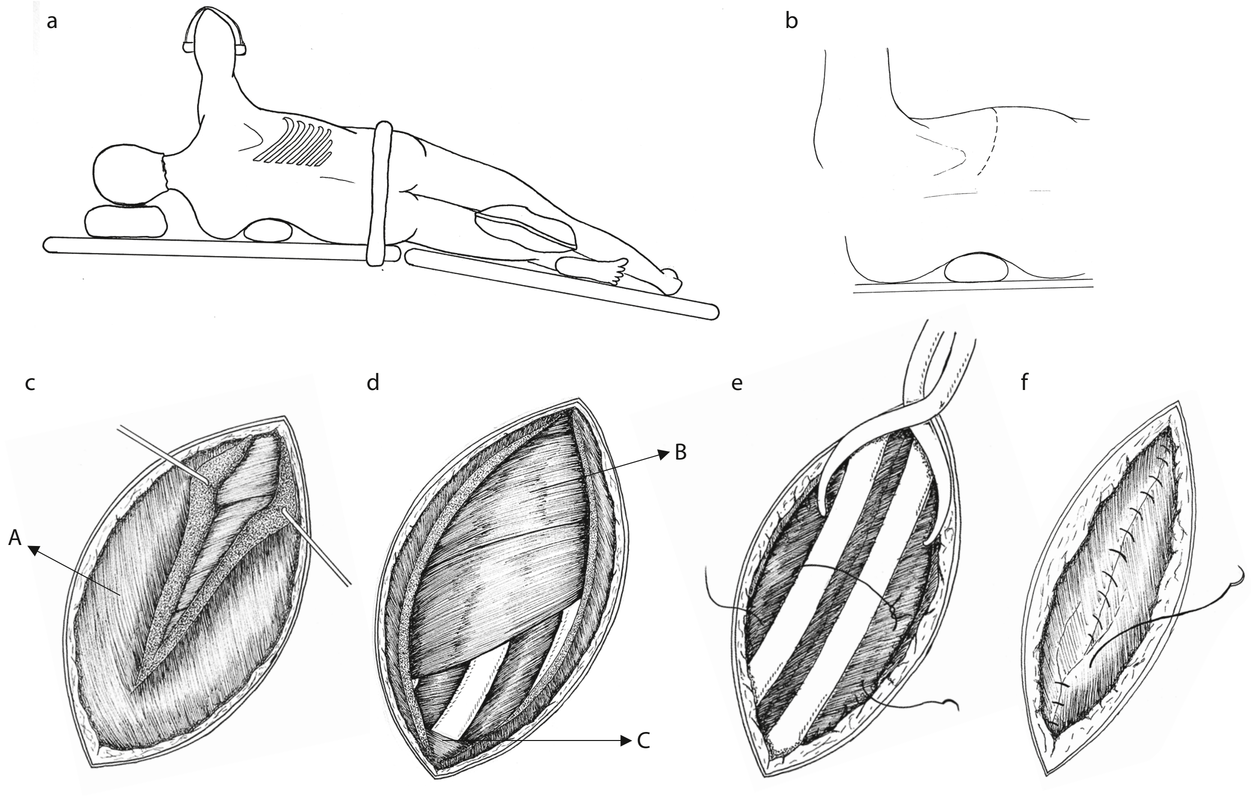
There are several surgical access routes to the structures inside the chest cavity. A brief description of each of the approaches is warranted for a better understanding and improved decision-making.

POSTEROLATERAL THORACOTOMY

Posterolateral thoracotomy is perhaps the most popular approach because there is maximum exposure of the contents of the chest cavity. The patient is placed in the lateral position, with the operative side facing upwards. To ensure that the patient is stable, the limb nearest the table may be flexed at the hip and knee, and the upper limb of the affected side straightened. The patient is further stabilised using tapes and sandbags. A rolled sheet or sandbag may be used under the chest to further open the intercostal spaces. Operating tables may also be positioned to assist in flaying the chest open (Figure 22.3a).



22.2 (a) Double-lumen tube. (b) Right-sided tube. (c) Left-sided tube. (Illustrated by Mahil Matthew Peter.) ⏎



22.3 (a) Posterolateral thoracotomy. Note the folded sheet under the chest and that the arm is positioned without traction, the lower limb is flexed and the patient is strapped to the table. (b) Skin incision made below the scapula tip and extended posteriorly between the scapula and spine. (c) A, latissimus dorsi. (d) B, serratus anterior; C, trapezius. May be cut or retracted and a hand passed over the ribs to count the intercostal space. The second rib is the highest palpable. (e) Rib-approximating sutures are taken just superior to the rib above the intercostal space opened and just superior to the rib below the intercostal space opened to avoid intercostal vessel injury. A towel clip is used to hold the ribs together. Note the position of the towel clip. (f) Closed in layers. (Illustrated by Mahil Matthew Peter.) ⏎

The skin is incised as shown in Figure 22.3b, ensuring that the incision is lower than the lowest point of the scapula when the scapula is lowered towards the hip. The first muscle encountered is the latissimus dorsi (Figure 22.3c). After this is cut along the skin incision, the trapezius may be dissected and retracted posteriorly, or partially cut, and the serratus anterior retracted anteriorly (Figure 22.3d). A plane is created just superficial to the ribs and a hand is passed up to palpate the highest rib, the second rib. The space below this is the second intercostal space. When the fifth intercostal space is to be entered, a cut along the superior margin of the sixth rib facilitates entry. This is best done with cautery to ensure haemostasis, as a constant trickle of blood from the wound can be a nuisance. The pleural space is entered with the lung collapsed to prevent lung damage. The muscle is cut only when necessary and a muscle-sparing thoracotomy is preferred.[3]

Rarely, a rib may need to be resected for better visibility inside the thoracic space. This can be done by stripping the periosteum from the rib and cutting the desired length of the rib.

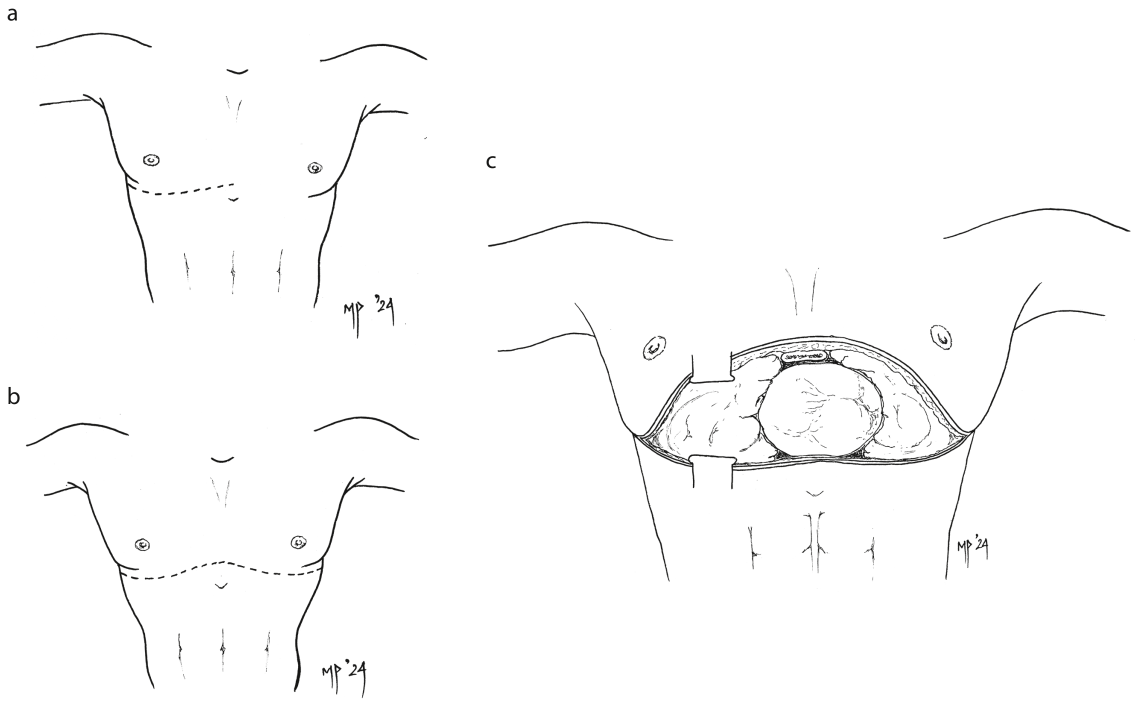
After the procedure in the chest cavity is completed, one or two chest tubes are placed before closure and connected to an underwater seal. One tube may be directed towards the apex and the other towards the diaphragm. These tubes help in the drainage of any collection and in the removal of air in the cavity to assist lung expansion.

Closure of the chest is by interrupted sutures placed above the rib and the lower intercostal space. Approximation is assisted by using a rib approximator or a blunt towel clamp while the sutures are tied (Figure 22.3e). After this, the muscles are closed in layers to restore normal anatomy (Figure 22.3f).

ANTEROLATERAL THORACOTOMY

For a left anterolateral thoracotomy, the patient is positioned supine with a sandbag under the left shoulder and the left upper limb positioned above the head and secured gently on the metal screen. It is important to avoid excessive stretching at the shoulder, which may result in temporary neurological damage.

An incision is made along the fifth rib extending from the anterior axillary line laterally to the border of the sternum medially (Figure 22.4a). A plane is developed below the breasts to retract the breast superiorly in women. The only muscle encountered here is the pectoralis major. The chest is entered as described earlier along the upper border of the sixth rib (or fifth rib if the fourth intercostal space is preferred). If the incision is extended up to the border of the sternum, care must be taken to identify, ligate and divide the internal mammary artery. A rib spreader,



22.4 (a) Anterolateral thoracotomy. (b) Incision extended to opposite side for a 'clamshell' thoracotomy. (c) Clamshell thoracotomy for access to both pleural cavities, the lungs and the heart. (Illustrated by Mahil Matthew Peter.)

placed in the middle of the incision, is usually adequate. If more space is required, the costal cartilages above, and below, can also be divided.

On completion of the procedure inside the chest cavity, closure is achieved after one or two chest tubes are inserted in the interspace below that of the incision. The ribs are first approximated with interrupted sutures and then the muscles, subcutaneous tissue and skin are closed in layers.

In an emergency, especially in chest trauma, this incision can be extended to the opposite side across the sternum (Figure 22.4b). Care must be taken to ligate both internal mammary arteries. This 'clamshell incision' (Figure 22.4c), although rarely used, may be helpful to assess and repair damage in chest injuries, when facilities for VATS are not available. Emergency resuscitative thoracotomies have had poor success rates, even in experienced hands.[4]

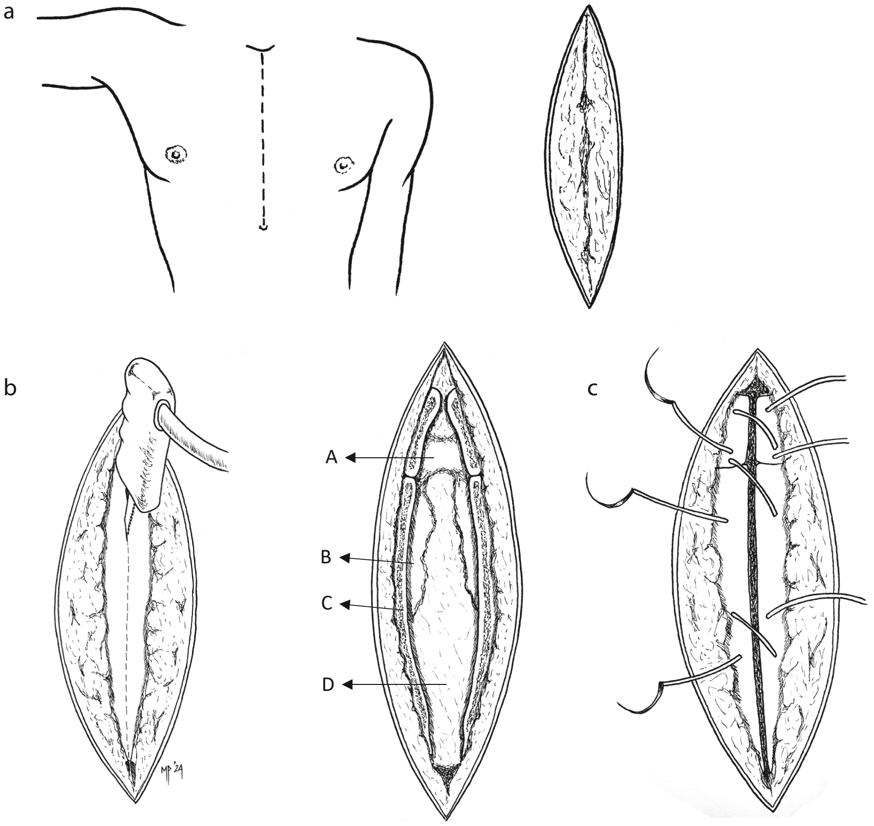
LATERAL THORACOTOMY (MUSCLE SPARING)

The patient is positioned in the same way as for a posterolateral thoracotomy. A small incision is made on either side of the mid-axillary line, not extending beyond the underlying pectoralis major anteriorly or the latissimus dorsi muscle posteriorly. Creating a plane superficial to the ribs is not required, and the chest cavity is entered as described, along the upper border of the rib with the lung deflated. This incision may be extended on either side if the need arises.

STERNOTOMY

The best exposure to the mediastinum is through a sternotomy. With the patient positioned supine, a midline incision is made extending from the manubrium sternum to the xiphoid process (Figure 22.5a). With the help of diathermy, the incision is deepened and the periosteum over the sternum is exposed and marked for a vertical sternal cut. The best way to cut the sternum is by using an electric, or pneumatic driven, saw – an instrument found only in operating theatres where cardiac surgery is performed (Figure 22.5a).

Another method of cutting the sternum is by using a Gigli saw. A long haemostatic clamp is passed along the undersurface of the sternum from the xiphoid



22.5 (a) Midline sternotomy incision with sternal saw. (b) Release of substernal tissue before placing retractor. A, innominate vein; B, thymus; C, sternum; D, pericardium. (c) Closure with sternal wires. (Illustrated by Mahil Matthew Peter.) ⏎

process to the manubrium notch, taking the utmost care to remain just along the undersurface of the sternum so as not to damage the heart, mediastinal structures or innominate vein. A Gigli saw is then fed to the upper end of the clamp and drawn below the xiphoid. The sternum is cut with perpendicular movements of the saw. It is very important to establish haemostasis along the raw edges of the sternum. This is achieved using diathermy along the edges and bone wax in the marrow. Before inserting the four-blade (or similar) retractor, the undersurface of the sternum is freed from the tissue to make space for the blades of the retractor and ease retraction (Figure 22.5b).

The sternum is closed with steel wires placed along the lateral border of the sternum, approximated, twisted and locked (Figure 22.5c). Sternal plates may also be used when available. A stable sternal approximation and closure is essential to help wound healing, prevent bleeding and prevent postoperative pain.

CERVICAL APPROACH

Parts of the superior mediastinum can be accessed through a cervical incision, superior and parallel to the clavicle and sternal notch of the manubrium sternum. Partially cutting the sternocleidomastoid muscle may facilitate better exposure and dissection. Mediastinal biopsies and operations for a retrosternal goitre may be performed through this route.

TRANSCLAVICULAR APPROACH

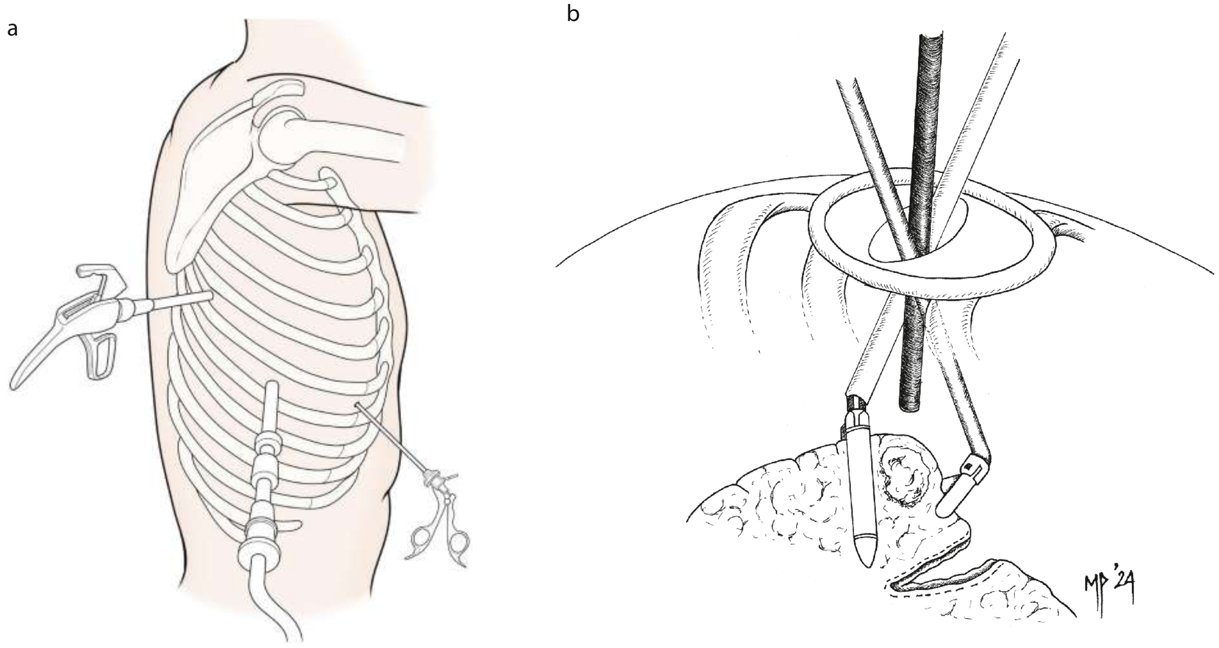
When further access is required and a cervical route is inadequate, the clavicle may be cut to expose the space between the clavicle and the rib cage. This is explained in Chapter 18. If an approach to the chest cavity is desired, the cervical incision can be extended along the lateral border of the sternum and the pectoralis major is reflected laterally. The chest cavity is then entered through the desired intercostal space as described earlier.

TRANSHIATAL APPROACH

This route is most useful during a laparotomy for a blunt injury if a diaphragmatic tear is found with herniation of abdominal contents. Reducing the contents back into the abdomen may require extension of the diaphragmatic tear along the muscle fibres, taking care to prevent phrenic denervation. An exploration of the chest cavity may also be performed during this time to exclude intrathoracic injury.

VIDEO-ASSISTED THORACOSCOPIC SURGERY

VATS has several advantages. The rib-spreading thoracotomy incision with the associated morbidity of



22.6 (a) VATS with three ports: two working ports anterior and posterior and one camera port in the mid-axillary line in the seventh or eighth intercostal space. (b) Uniportal VATS. (b, illustrated by Mahil Matthew Peter.) ⏎

pain and muscle damage is avoided. In addition, it serves as an exploratory procedure, even in trauma. With the patient in the lateral position, ports are placed in three positions – a camera port and two working ports – although the site and function of each port may vary according to the surgeon's preference. The first port is the camera port inserted through an incision furthest away from the dissection site. This is usually the seventh or eighth intercostal space in the anterior axillary line. The second, the main working port, is inserted in the fourth or fifth intercostal space between the anterior axillary line and mid-clavicular line. The third port is posteriorly placed , at the fifth or sixth intercostal space adjacent to the scapula (Figure 22.6a).[5,6]

PROCEDURES FOR A GENERAL SURGEON

THORACIC PROCEDURES

Chest tube insertion

This is perhaps the most important thoracic procedure that a general surgeon should know. A chest tube insertion is indicated in several situations, including haemothorax, pneumothorax, infected pleural effusions and after opening the chest for any thoracic surgery. Chest tube insertion should also be considered as a prophylactic step in chest trauma when an exploratory laparoscopy is being considered. This is because an apparently insignificant lung contusion, a small pneumothorax or an unrecognised diaphragmatic injury could lead to a tension pneumothorax in response to positive pressure ventilation at anaesthesia.

The easiest site for chest tube insertion is the 'safe triangle', which is bound posteriorly by the mid-axillary line, anteriorly by the lateral border of the pectoralis major muscle and inferiorly by a line drawn along the fifth intercostal space meeting both of the above lines (Figure 22.7a). While this site is chosen for its safety, it may not be appropriate for loculated effusions, where an ultrasound-guided site is chosen for insertion.[7,8]

A small incision is made on the skin on the rib immediately below the intercostal space where the chest tube is to be inserted. The incision is deepened through the subcutaneous tissue to the muscle layer. A haemostat clamp is used to develop a space through the incision and is directed towards the intercostal space, just above the superior border of the rib. This ensures that the intercostal neurovascular bundle is protected. Once the space is developed, it can be probed by the finger to reach the pleura and to ensure that the incision is sufficient for the selected chest tube.

Chest tubes are available in different sizes and all have multiple holes to facilitate drainage. A small tube is sufficient for a pneumothorax, but a larger diameter tube will be needed for adequate drainage of a haemothorax. It is recommended that the last hole must be at least 3–5 cm inside the pleural cavity. That means, considering the thickness of the chest wall, that the marking on the skin must be at least 8–10 cm from the tip to allow 3 cm inside the pleural cavity and 5 cm as the length of tube to traverse the chest wall. If the chest tube is too long, it may be trimmed at an angle (Figure 22.7b). The chest tube is held in a curved haemostat clamp (Figure 22.7c) and inserted through the incision, with minimal pressure, so that it enters the pleural space. A gush of fluid/blood or air is confirmatory of entering the pleural space when the tube is inserted. The clamp may be removed and the tube advanced to the desired level.

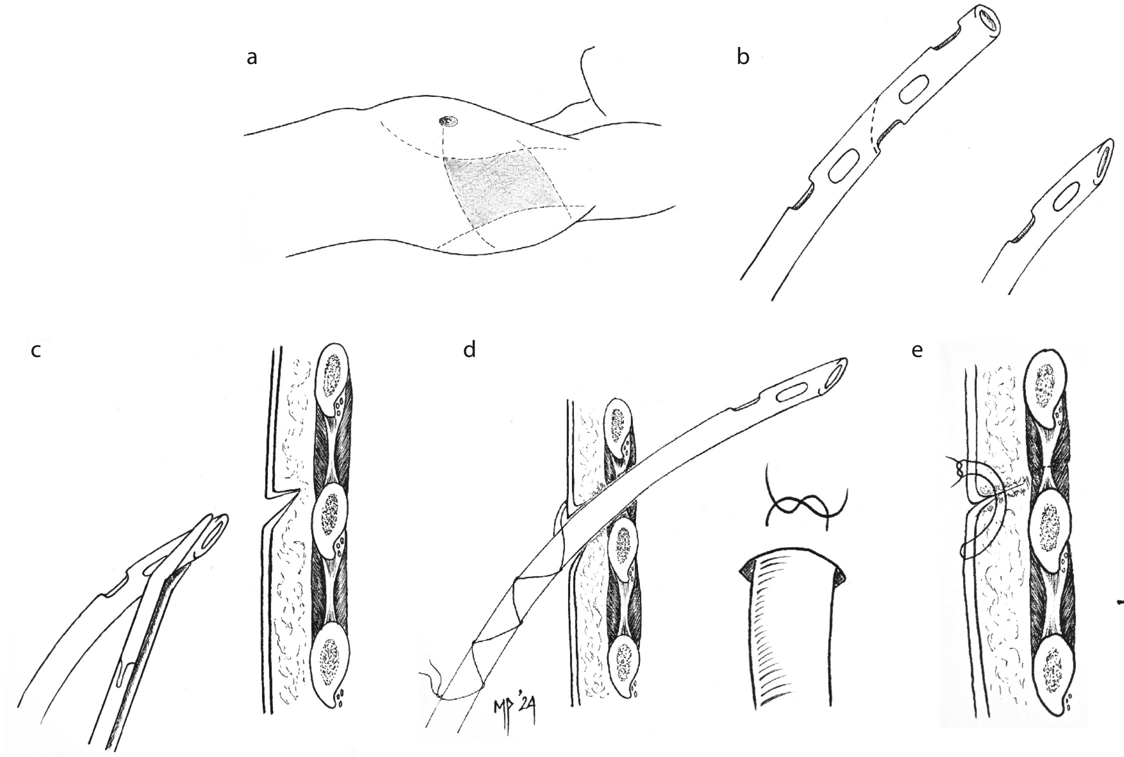
Fixation of the tube is of the utmost importance to ensure that it does not migrate through the track in the chest wall. A loosening of the skin around the tube, or migration of the tube, such that a chest tube hole is out of the pleural cavity and in the chest wall, could lead to surgical emphysema.

Fixation is best achieved with a mattress suture placed in or near the incision for the chest tube insertion. A single simple knot is placed on this suture and the strands are then encircled around the tube (Figure 22.7d).

The removal of the chest tube is fraught with the danger of air leaking into the pleural space and causing a pneumothorax. It is best to ask the patient to hold their breath during a Valsalva manoeuvre and then the tube can be removed while pressing down on the incision with a piece of gauze. The loose suture with a single tie can then be tightened and knotted (Figure 22.7e). The angled path of the chest tube insertion also helps to prevent pneumothorax.

Thoracotomy for pleural drainage

Accumulation of fluid in the pleural space can lead to collapse of the lung and, in worst cases, an empyema with its subsequent sequelae. Drainage of this fluid is achieved by needle aspiration or chest tube insertion. Ultrasound-guided needle aspiration is recommended to avoid injury to the lung, liver, spleen or other structures. The only indication for open pleural drainage is when the fluid is loculated in pockets or is too thick to be drained by needle aspiration or by chest tube insertion. Depending on the site of the accumulation of fluid, confirmed by an ultrasound, an appropriate approach is chosen – a small lateral thoracotomy, which in most cases will suffice, is the first choice and the incision may be extended if necessary.

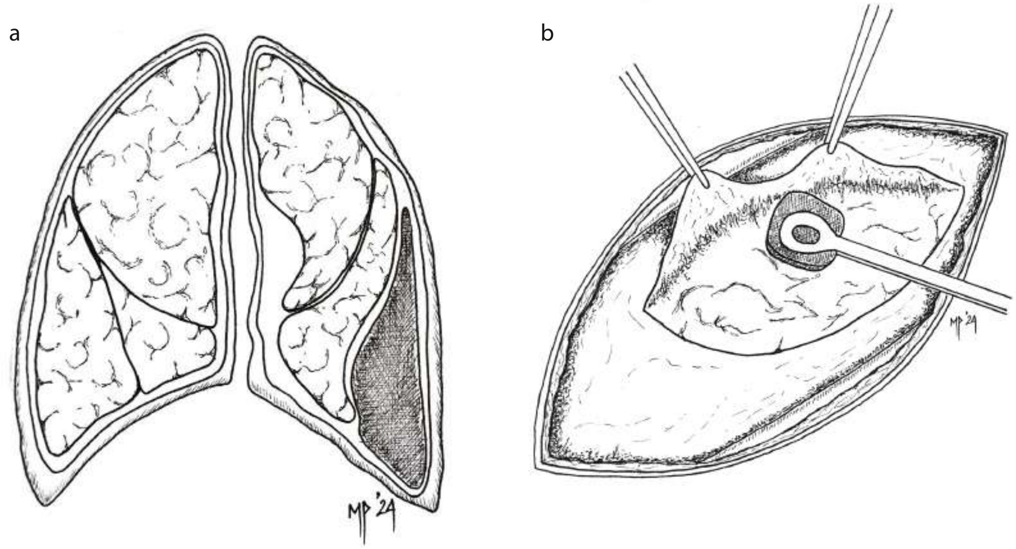


22.7 Chest tube insertion. (a) Safe area to insert the chest tube: above the sixth rib in the space between the posterior border of the pectoralis major and the mid-axillary line. (b) The chest tube should be cut to the desired length such that at least 10–12 cm from the last hole is at the skin. (c) An incision should be made over the rib and the incision deepened using a haemostat clamp onto the upper border of the rib. Stay sutures should be taken with long ends, which are used to secure the tube. The tip of the chest tube should be held in the haemostat clamp and inserted through the incision into the pleural cavity, just above the rib, then the clamp should be withdrawn. (d) The tube is then secured with sutures. (e) The mattress sutures are then tightened after removal of the tube. (Illustrated by Mahil Matthew Peter.)

Through this approach, loculi may be separated and diseased pleura peeled and excised. In the absence of VATS facilities, this approach can also be used to take lung or pleural biopsies. It must be noted that a chest tube should be inserted for all these procedures, and the closure of the chest wall is achieved as described earlier.

Decortication

An empyema is a collection of pus in the pleural space between the visceral and parietal pleura (Figure 22.8a). In the early stages, exudative fluid accumulates in the pleural cavity (stage 1) and drainage is achieved by aspiration or chest tube insertion. When pus has formed, but the pleura is not significantly thickened (stage 2), removal of the pus and debridement of the pleural space will suffice for the lung to expand and fill the thoracic cavity. Removal of the fluid and a simple debridement, when needed, is sufficient in such situations and the lung expands to its full capacity. However, when the empyema is long standing, with pleural thickening (stage 3), the underlying lung is entrapped, resulting in failure of the lung to expand. Decortication is the only option and this can be achieved by either open thoracotomy or VATS.[9] The principle remains the same. Once the pus is drained, the wall of the empyema is removed entirely, including both the parietal and the visceral thickened pleura covering the lungs. The visceral pleura is peeled off the surface of the lung after establishing the correct plane of dissection. Once a small portion of the thickened pleura is lifted off the lung, it is held with forceps and, with blunt dissection, the underlying lung is separated from it (Figure 22.8b). Lung isolation intubation is helpful to prevent spillage, and the countertraction offered by the inflating lung helps maintain the plane of dissection. It is possible that the thickened pleura may have to be peeled in pieces. Ensuring that the underlying lung expands is crucial for the decortication to be successful. During this peeling, it is common to cause minor injuries to the lung, resulting in small air leaks. A large tear in the lung, which can cause a significant air leak and thus preventing expansion of the lung, will have to be sutured with continuous sutures of 4/0 or 5/0 suture



22.8 (a) Left empyema, an encapsulated cavity of pus. (b) The thick layer of visceral pleura is separated from the underlying lung. (Illustrated by Mahil Matthew Peter.) ⏎

material. However, small leaks usually close spontaneously and are best managed by leaving the chest tubes *in situ* until the air leak has stopped.

Chest tubes are connected to low-pressure suction and kept in place until the air leak stops, indicated by cessation of bubbles in the first bottle. Cessation of movement of the water level in the first underwater seal during respiration indicates that the lung has fully expanded and the expanded lung is in contact with the parietal pleura or chest wall.

It might be prudent to clamp the chest tubes for a few hours and take a chest X-ray to confirm lung expansion and the absence of a pneumothorax. Once satisfied, the chest tube(s) may be removed. Another chest X-ray after removal is mandatory. While surgery in stages 1 and 2 is relatively easy, surgery for stage 3 can be complicated and may result in multiple air leaks. In this situation, the chest tubes may need to remain for a longer period.[10,11]

Pleurodesis

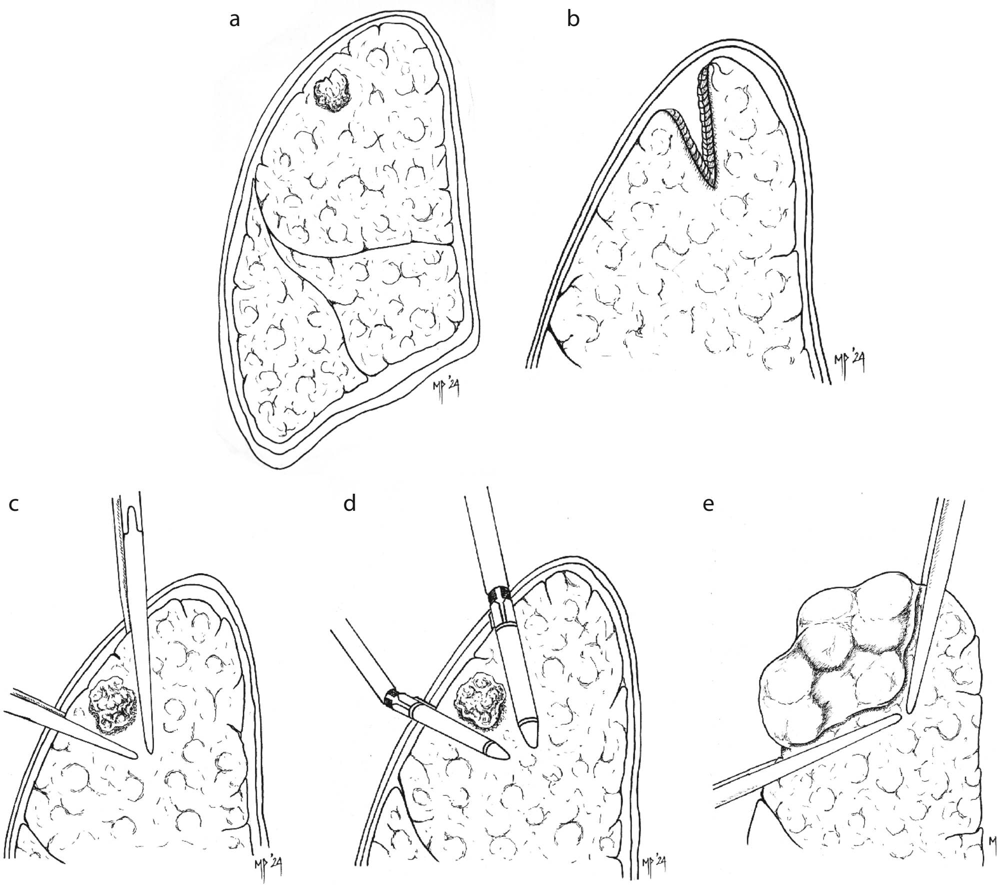
Recurrent pleural effusions can be challenging to treat. Malignant effusions tend to recur and, unless drained, can cause pulmonary complications. Repeated drainage is fraught with the danger of infection. In such situations, pleurodesis is often the best solution. Pleurodesis involves adhesion of the visceral and parietal pleura, thereby obliterating the pleural space. This is achieved by chemical pleurodesis, by introducing chemicals that induce pleural reaction or by mechanical abrasion of the pleura, which is perhaps the most effective method.

Pleurodesis is best achieved with VATS. Both methods – chemical or mechanical – can be easily performed using this technique. VATS also has the advantage of removing fibrous strands that may make loculated effusions not amenable to pleurodesis. In the absence of the availability of VATS, chemical pleurodesis may be attempted through a chest tube. The 50–100 mL pleurodesis solution is injected through the tube and the tube is clamped. The patient is initially positioned supine. The position is changed every 15 minutes – lateral on each side and prone. The tube is unclamped after an hour and then removed. When there are multiple loculi, and VATS is not available, a small lateral thoracotomy may be required to release the strands prior to pleurodesis. Tetracycline, doxycycline, bleomycin, dilute Iodopovidone and sterile asbestos-free talc have all been used for chemical pleurodesis.[12,13]

Lobectomy/Wedge resection

A thorough knowledge of the bronchial tree is necessary when a lobectomy is performed. Meticulous dissection is necessary to separate the lobes and, when the demarcation is not complete, small air leaks through the lung tissue may occur. The use of staplers has reduced the incidence of bronchial leaks, even in inflammatory conditions.

Wedge resections, or non-anatomical resections of the lung, are indicated in several benign conditions – bullae, lung biopsy, and in some malignant conditions such as solitary lung nodules (primary or secondary) (Figure 22.9a). Wedge resection in malignancy depends on the availability of backup services and the support and backup of an oncology team. Nevertheless, in resource-limited settings and when referral is difficult, an initial biopsy, even in



22.9 (a) Solitary nodule. (b) Non-anatomic resection of lung. (c) Wedge resection between clamps. (d) Wedge resection using a stapling device through VATS. (e) Wedge resection of bullae. (Illustrated by Mahil Matthew Peter.) ⏎

malignancy, may be helpful in determining further treatment.

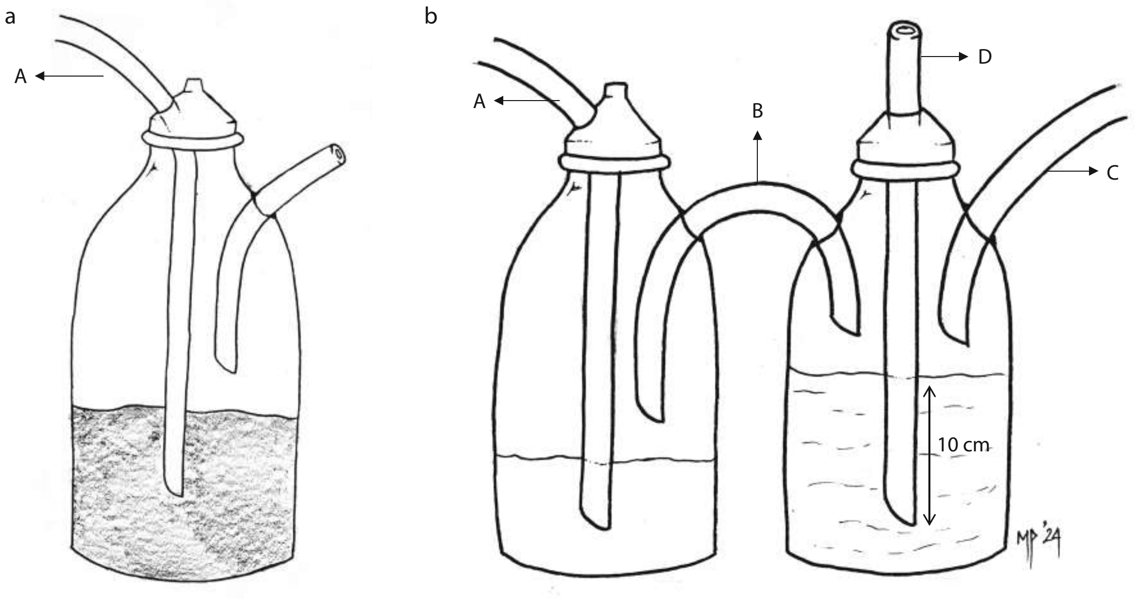
Non-malignant conditions are easier to treat and may be cared for even in a non-specialised unit. Non-anatomic resections, and wedge resections, can be attempted in non-malignant conditions with the help of mechanical stapler devices (see Figure 22.9b–e). If staplers are not available, a resection between clamps, followed by oversewing of the free edges, gives good results. Wedge resections can easily be accomplished by VATS and have been found to be comparable to results using robotic surgery.[14,15]

Mediastinal tumours

Primary tumours of the neck, extending retrosternally into the mediastinum, and primary mediastinal tumours are occasionally encountered. While neck tumours with mediastinal extension can be approached through cervical incisions, some mediastinal tumours require opening the chest, through either a thoracotomy or a sternotomy. If VATS facilities are available, this route would be preferred, as it results in less morbidity, even though an incision is needed for the delivery of the tumour. Care is taken to protect the phrenic nerve and the innominate vein. Removal of tumours of the thymus must be coordinated with a neurologist when treating patients suspected of myasthenia gravis to ensure appropriate treatment and a smooth postoperative recovery. The classic approach for radical thymectomy is a sternotomy, but partial sternotomies and VATS should be considered.[16] Special processing of the biopsy specimen may be required, and it is advisable to send the specimen to a specialist centre.

CHEST TRAUMA

In speciality hospitals, chest trauma is usually managed by an experienced trauma team. In small hospitals across the world, specialist trauma teams are not available but patients are still brought to these hospitals in an emergency. Considering this, it is important for a general surgeon to be able to manage chest trauma. Chest trauma may present as part of general trauma to the emergency department. It has been noted that less than 10% of patients presenting with



22.10 (a) Underwater seal for chest tubes made of intravenous bottle. (b) The second bottle with three tubes. A, to patient; B, connected to first bottle; C, connected to suction; D, tube kept under water and left open to the air on the other end. The distance below the water level determines the negative suction applied (minus 10 cm of water). This prevents high suction being applied to the pleural cavity, which can damage the lungs. (Illustrated by Mahil Matthew Peter.) ⏎

chest trauma, as part of a general trauma service, need surgical intervention for the chest. Practical knowledge of assessing a trauma patient for chest injuries and knowing when to intervene helps to save lives.

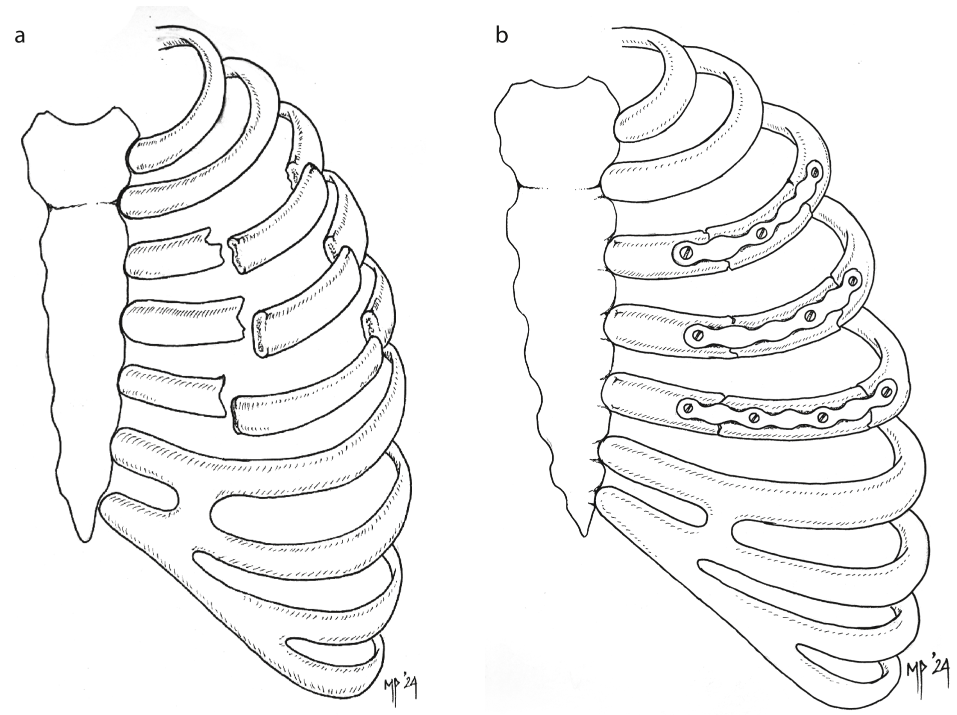
Chest trauma can be blunt or penetrating. Blunt injuries are more common as part of motor vehicular trauma and crush injuries in construction-related accidents. The structure of the chest wall comprising the ribs, sternum, clavicles and spine makes it uniquely resistant to all but very severe forms of blunt trauma. The mediastinal structures are well protected behind the sternum, and the lungs on either side of the mediastinum are shielded by a partially malleable chest wall. Single or even multiple rib fractures do not by themselves hamper the lung function, but the associated haemothorax, pneumothorax and pain cause reduced lung expansion and can result in complications such as lung collapse and pneumonia.

A penetrating injury can cause damage to the lungs or the mediastinal structures depending on the depth and site of injury. A thorough clinical assessment of such a patient, followed by optimal radiological imaging, where possible, is of the utmost importance before deciding on the further course of action.[8] Remote hospitals should have their own protocols depending on the availability of imaging modalities and medical expertise.[17]

In order of importance, the following must be checked:

- *Adequate air entry.* Obstruction to the airway by blood or vomitus, aspiration of a foreign body or compression of the trachea by injury to the head of the clavicle must be looked for if the patient has difficulty breathing. Establishing the airway can be achieved by removal of the foreign body through suction and sometimes with just a finger swipe through the mouth. Reduction of external compression must be carried out immediately guided by clinical judgement.

  If the air hunger persists, tracheal or bronchial injury, or pneumothorax, must be suspected and looked for. Insertion of a chest tube is performed at the bedside, and this helps instantaneously in the case of a pneumothorax. However, if a tension pneumothorax needs to be immediately relieved, a large bore venous catheter can be placed in the lateral fourth or fifth intercostal space. If this causes relief, a chest tube can be inserted. If the insertion of a chest tube will be delayed, an intravenous tube may be attached to the venous catheter and placed in an underwater seal (made from intravenous fluid bottles) (Figure 22.10a, b). Alternatively, the finger of a rubber glove, with the tip cut off, can be tied to the intravenous catheter, which functions like a one-way valve. If there is no air entry on auscultation, with associated hypovolaemic shock, a haemothorax must be suspected and a chest tube inserted.[18]



22.11 (a) Flail chest: two or more ribs broken in two or more places. (b) Early surgical stabilisation of rib fractures with plates may be required in multiple fractures. (Illustrated by Mahil Matthew Peter.) ⏎

- *External injury to the chest wall.* Injury to the chest wall must be noted and, if there is an injury exposing the underlying lung or pleural space to air, this must be closed with a sealant dressing. A chest tube inserted away from the injury will relieve the pneumothorax, drain fluid and restore air entry. A chest tube insertion with an underwater seal (Figure 22.10) may be the only procedure required to ensure adequate lung expansion in a laceration/contusion or penetrating injury of the lung.
- *Haemodynamic stability.* Once the airway and ventilation have been secured, haemodynamic stability is restored. Hypotension can be a result of a massive haemothorax or cardiac tamponade, especially in penetrating injury. A bedside echo can confirm the diagnosis, and a pericardiostomy (described later) can be performed. If imaging facilities are available, a catheter can be introduced into the pericardial space using the Seldinger technique. Once the blood is drained, the blood pressure improves. However, if the pericardial effusion is due to a penetrating injury or injury to the myocardium, a chest exploration is warranted.

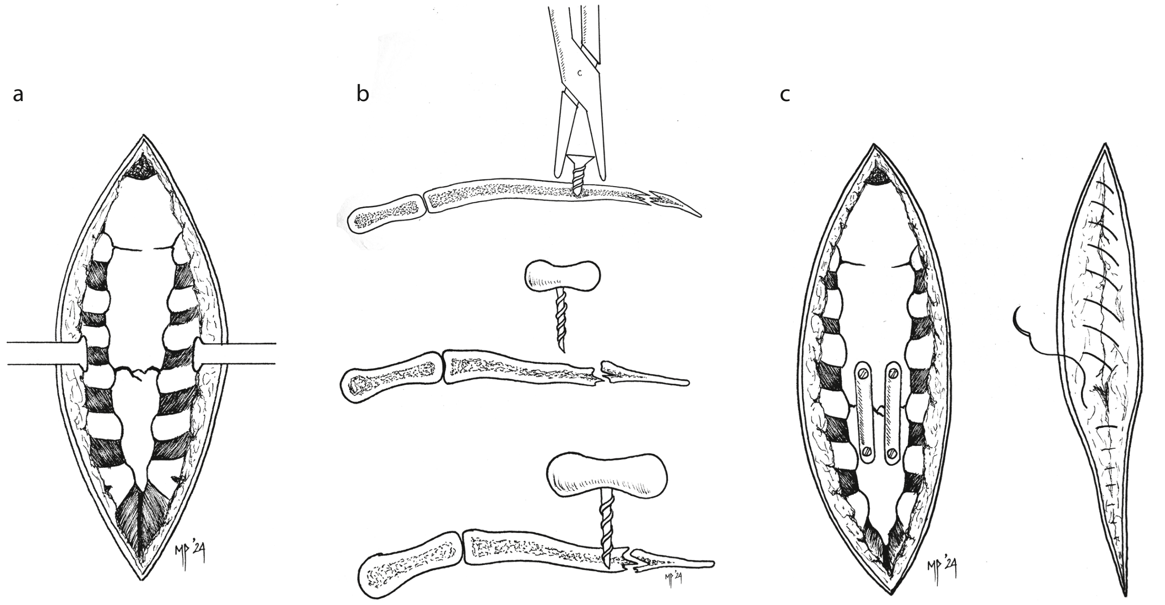
After initial assessment, establishing an airway and stabilising the patient haemodynamically, the focus can move to managing the chest injuries. Emergency thoracotomy or a clamshell incision have been performed in the emergency department with mixed results.[19] VATS has been found to be most useful, yet is underutilised as an exploratory and diagnostic tool in chest trauma.[20] The most common injuries and their management are as follows.

Rib fractures/Chest wall stabilisation

Most chest wall injuries and isolated rib fractures do not require surgical intervention for chest wall stabilisation. Pain relief and positive pressure ventilation suffice when the patient is unable to breathe adequately. In addition to oral medication, pain relief can be achieved by intercostal blocks or a thoracic epidural, in the absence of any other injury that would contraindicate epidural use.[21–23]

Flail chest

This is a condition in which two or more ribs are fractured in more than two places (Figure 22.11a). The fractured segment of the chest wall then moves independently to the rest of the chest wall. The flail segment is drawn inside the chest during inspiration and bulges outwards during expiration. When this is observed, the patient may need to be intubated and positive pressure ventilation initiated. A few days of ventilation is usually sufficient to stabilise the chest. Rarely, the ribs may be ‘fixed’ by interrupted sutures through the rib or even through intercostal spaces.[24]



22.12 (a) A midline incision exposing the sternal fracture. (b) A screw inserted in the depressed segment with a portion left outside. The screw is held by a clamp and the depressed segment is pulled up. (c) Two plates are fixed on the sternum for stabilisation. (Illustrated by Mahil Matthew Peter.) ⏎

Surgical stabilisation of rib fractures with plates has proved beneficial in reducing morbidity, pain and ventilation requirement (Figure 22.11b).

Sternal fractures

This is a rare complication of chest trauma. A small segment of the sternum may be fractured and depressed. An exploration is done through a vertical incision on the sternum. The sternum is exposed and the fracture identified (Figure 22.12a). In order to lift the depressed segment, a screw is inserted in the segment, leaving the head of the screw above the surface. The depressed segment can be lifted to align with the rest of the sternum by traction on the screw (Figure 22.12b). An appropriately sized plate can then be screwed in place (Figure 22.12c).[25]

Injury to the great vessels and heart

Blunt injuries to the great vessels often go unnoticed and can present several days after the injury. Penetrating injuries present with haemothorax, haemopericardium, cardiac tamponade and hypotension and often lead to haemodynamic shock. It is uncommon for patients with such severe injuries to reach the hospital alive. A quick assessment and manoeuvres such as chest tube insertion, pericardiostomy, and fluid and blood replacement are critical in the initial hours after presenting to the hospital. After such initial treatment, imaging plays a crucial role in deciding further surgical intervention. Depending on the site of internal injury, the patient is explored with a view to surgically correct the injury or to stabilise the patient and render them suitable for transfer to a specialised centre. Aortic tear and dissection may occur as a result of abrupt deceleration in the region of the ligamentum arteriosum, just distal to the left subclavian artery. Haemodynamically stable patients are best managed conservatively and referred to a cardiac centre for definitive treatment. Other injuries may take higher priority for intervention.[26]

Diaphragmatic injury must be looked for during an exploratory laparotomy. After the herniated contents, if any, are reduced, the diaphragm, which may need to be opened further to facilitate reduction, is closed either directly or using a mesh.

Oesophageal injury

Oesophageal tears usually present some time later after the injury and are mostly seen in the lower third of the oesophagus. The best approach to the oesophagus is through the left side of the chest, by either VATS or open thoracotomy.

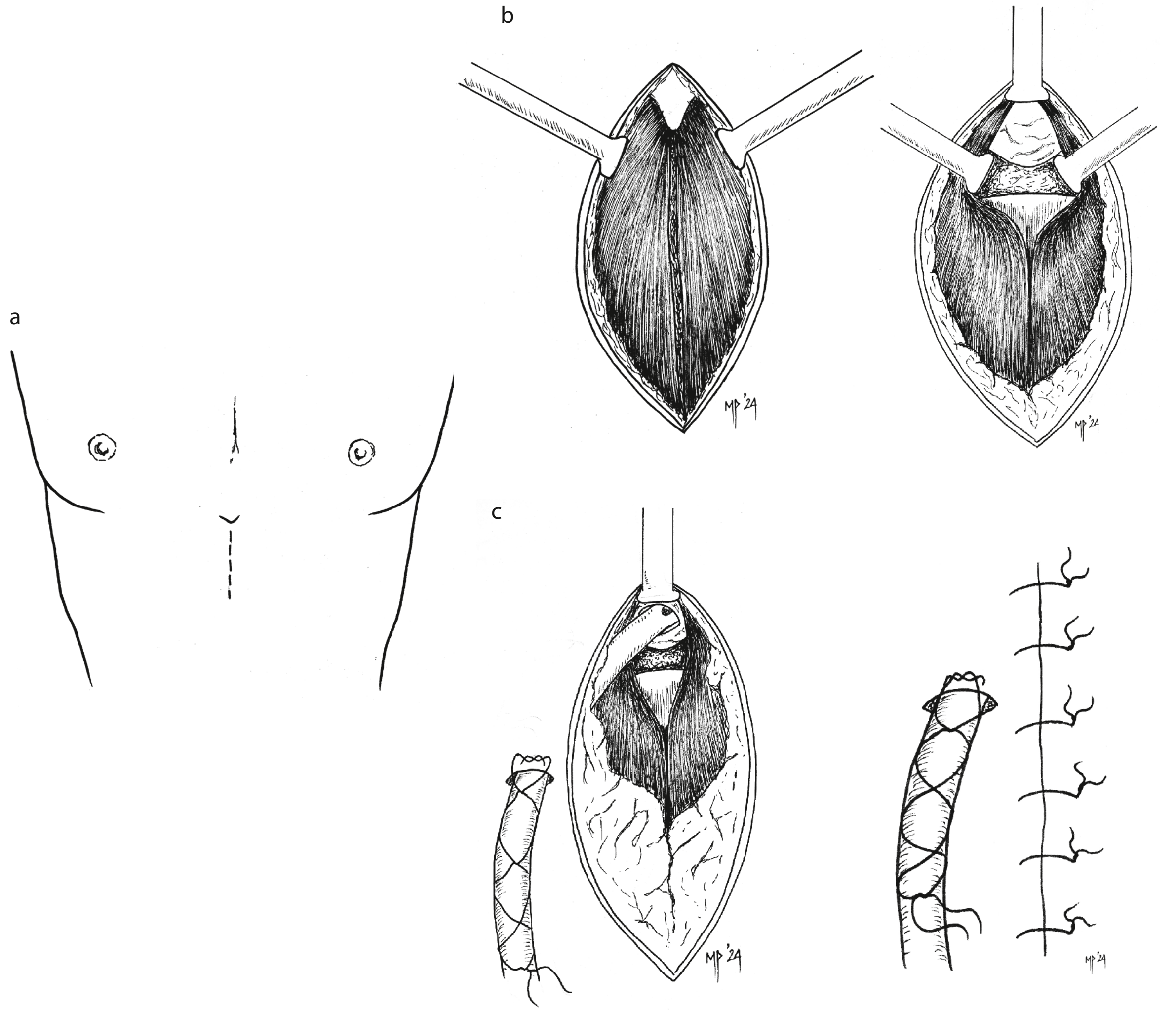
After cleaning the area and identifying the area of the tear, the oesophagus is dissected carefully, avoiding injury to the vagus nerve. Any necrotic surrounding tissue is debrided. The diaphragmatic hiatus may need to be incised and extended to facilitate visualisation of the lower end of the tear. It is usual to find that the mucosal tear is much longer than the muscular tear, and extending the muscle tear up to the full extent of the mucosal tear may be necessary. Interrupted sutures are used to close the defect in two layers. An ‘inflation test’, using a Ryles nasogastric tube in the oesophagus may be carried out to check for leaks. A Ryles tube is kept *in situ* in the postoperative period until the oesophagus heals completely. If the surrounding tissue seems unhealthy, a vascular flap of a strip of intercostal muscle and parietal pleura with intercostal vessels may be used to buttress the oesophagus.[27]

SURGERY ON THE HEART AND GREAT VESSELS

Pericardiostomy

Pericardial effusion and haemopericardium can cause tamponade and decrease cardiac output. An immediate intervention to remove the fluid and restore cardiac output may be required, especially in situations where cardiac surgical facilities are unavailable.[28] A 4–5 cm vertical midline incision from the xiphisternum extending towards the umbilicus is performed (Figure 22.13a). The incision is deepened onto the xiphisternum. It is convenient to excise the xiphoid process to proceed unhindered (Figure 22.13b). Once that is done, the diaphragm will be visible in the upper part of the incision, under the sternum. The diaphragm is cut vertically in the midline. Since the pericardium is adherent to the diaphragm here, the pericardium is penetrated through the diaphragm with blunt dissection using a haemostatic clamp. There is an immediate gush of fluid/blood. The space is widened to allow insertion of a drainage catheter. A large bore chest catheter is introduced through a small incision made 3 cm to the right and alongside the original incision (Figure 22.13c). The catheter is fixed like a chest tube, as described earlier, and the main incision is closed in layers. The drainage catheter is removed when there is no further drainage.

Pericardiostomy may be achieved percutaneously. A long needle is inserted just below the xiphoid process pointing towards the left shoulder. It is gradually



22.13 (a) Midline subxiphoid incision. (b) Excision of xiphoid process. (c) Insertion of a tube through a separate incision into the pericardium. (Illustrated by Mahil Matthew Peter.) ⏎

advanced towards the pericardial cavity. When fluid or blood is aspirated, a flexible wire is introduced through the needle. The needle is removed and, after a dilator is passed over the wire to widen the track, a catheter (a pig tail catheter used in urological procedures, or similar, will suffice) is introduced over the wire, into the pericardial space. The use of a 'C-arm image intensifier', which is used commonly in the treatment of fractures, is beneficial to accurately place the needle and the catheter.

Pericardiectomy

Pericarditis can be effusive, with a collection of fluid in the pericardial cavity, or constrictive, which results in the thickening of the pericardium. When the pericardium is thickened and fibrosed, the pericardial cavity is reduced, thereby hampering cardiac filling. The patient presents with peripheral oedema, engorged veins and raised superior vena cava pressures. The constriction over the ventricles prevents cardiac filling during diastole. Lower ventricular volumes lead to lower cardiac output. Relieving this constriction by excising the pericardium is the only option.

This is best achieved via a sternotomy in order to excise the entire pericardium, leaving a band of pericardium along both phrenic nerves so as not to cause damage that may result in phrenic nerve palsy.

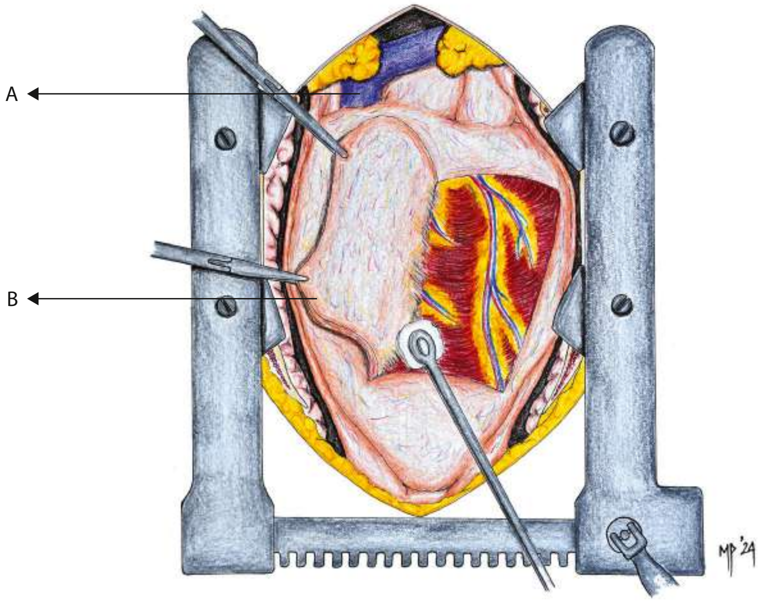
The aim of pericardiectomy is to remove the parietal and visceral pericardium, which are fused together and are adherent to the underlying heart. In severe cases, there is a danger of damaging the cardiac muscle and coronary vessels during dissection. The correct plane of dissection is of the utmost importance. Keeping the epicardial coronary vessels as a guide and ensuring the dissection is superficial to the vessels is helpful. The bulging heart that occurs when a small window is made in the pericardium assists by providing countertraction for dissection. It is advisable to use blunt dissection with a gauze and to restrict the use of sharp dissection to only those situations when the adhesions are very tough or calcific (Figure 22.14).

Partial pericardiectomy can be performed through a left anterolateral thoracotomy but a sternotomy is preferred when a complete pericardiectomy is to be achieved. The pericardium over the left ventricle is usually removed early, followed by the pericardium over the right ventricle, then pericardium over the atria and finally the vena cavae are freed.[29,30]

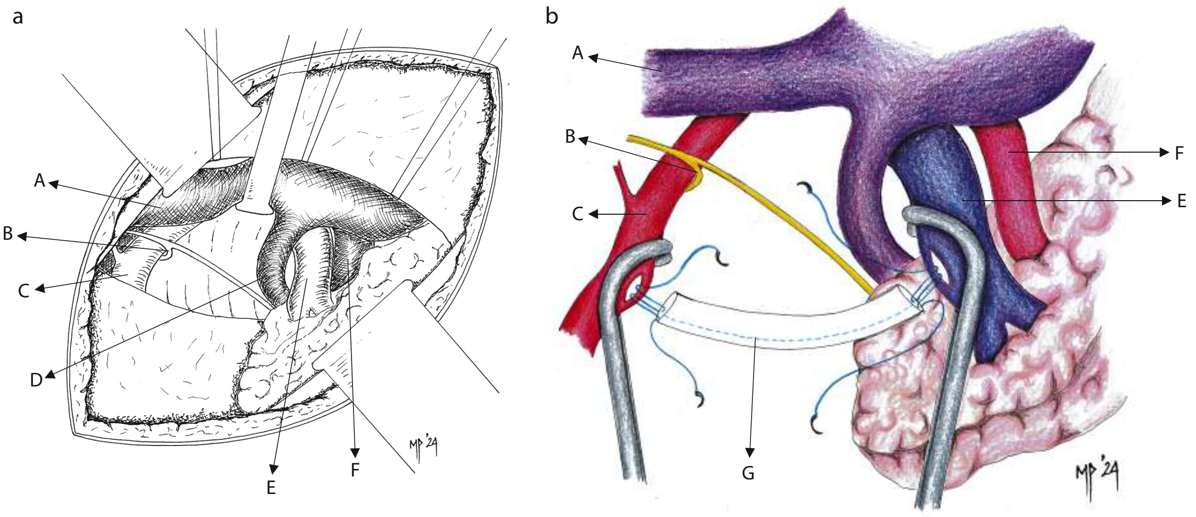
Such constrictive pericarditis is usually a sequela of an inflammatory process, often due to tuberculosis. Treatment of tuberculosis must be initiated.

Blalock–Taussig shunt

In an ideal scenario, early accurate diagnosis of structural defects in children with congenital cyanotic heart disease followed by early surgery is recommended. However, this is difficult in resource-limited situations and where paediatric cardiac surgery is limited to only a few centres. Early referral is also not always possible.



22.14 Midline sternotomy with the pericardium being peeled away, revealing the epicardial vessels. Blunt dissection is preferred. The same can be achieved through a left anterolateral thoracotomy. Care is taken to preserve both phrenic nerves. A, superior vena cava; B, thickened pericardium. (Illustrated by Mahil Matthew Peter.) ⏎



22.15 (a) Right thoracotomy. The right pulmonary artery is dissected free. The azygos vein may need to be ligated and divided. Care is taken not to damage the recurrent laryngeal nerve. Multiple loops may be used around the pulmonary artery during anastomosis if there is inadequate space for a clamp. The right lung is retracted inferiorly and posteriorly. (b) One end of the PTFE graft is anastamosed to the subclavian artery and the other end to the pulmonary artery. Care is taken to de-air the graft with heparinised saline. A, superior vena cava; B, recurrent laryngeal nerve; C, right subclavian artery; D, azygos vein; E, right pulmonary artery; F, right superior pulmonary vein; G, PTFE graft. (Illustrated by Mahil Matthew Peter.) ⏎

When referral is not possible, or when surgical repair of the defect is to be undertaken at a later stage, palliative shunt surgery is considered an option in children who are very symptomatic.

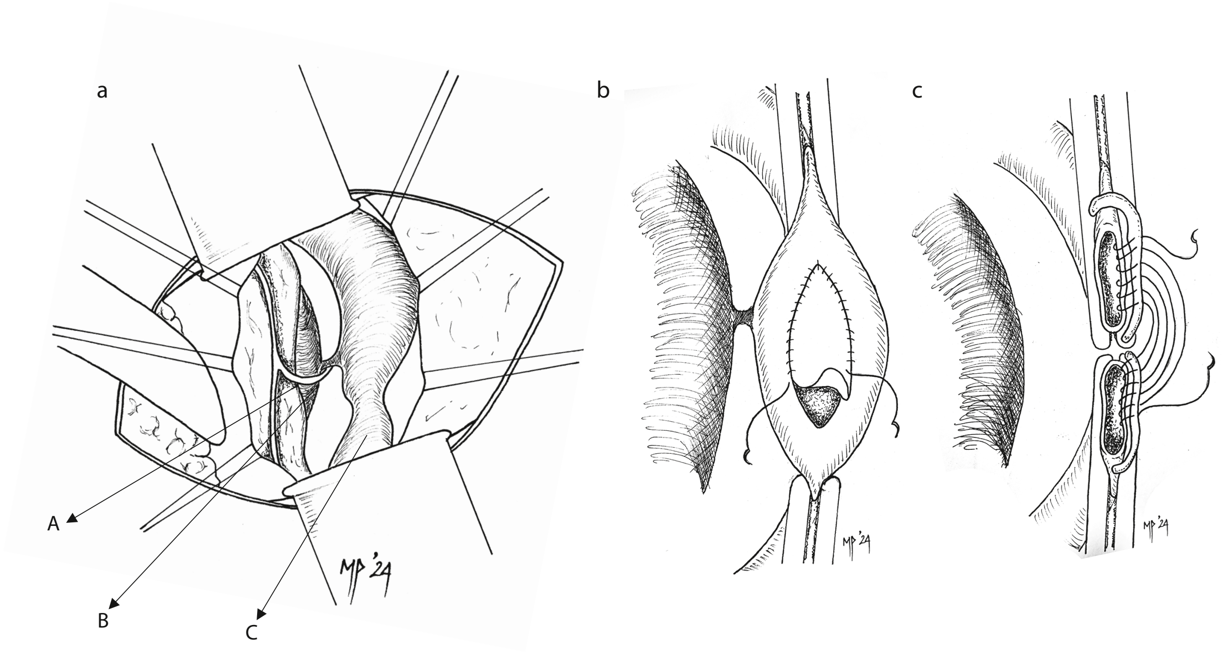
Cyanotic conditions that are a result of inadequate blood supply to the pulmonary circulation will benefit from surgery to improve circulation to the pulmonary arteries. Tetralogy of Fallot and pulmonary atresia are examples of such conditions. When interventional cardiology facilities are available, stenting a patent ductus arteriosus may be considered but, in remote areas and resource-limited settings, a palliative or temporising surgical treatment is considered.[31] If a shunt is to be planned, several options may be considered. The modified Blalock–Taussig shunt is probably the most popular option and technically the least challenging. Anaesthesia support is crucial for this surgery to be successful.[32,33]

A right thoracotomy (or left in patients with a right-sided aortic arch) in the fourth intercostal space is preferred. The lung can be retracted with a malleable retractor. The subclavian artery is identified and dissected free. The pericardial fold under the right phrenic nerve is dissected and the right pulmonary artery is isolated. The superior vena cava is retracted anteriorly to facilitate dissection (Figure 22.15a). The site of anastomosis is identified and tapes are passed with one proximal and the other distal to the proposed site of anastomosis. The subclavian artery is dissected and cleared of surrounding tissue allowing a side-biting vascular clamp to be applied. A 4 mm or 5 mm polytetrafluoroethylene (PTFE) graft is cut to an appropriate length such that one end is bevelled and anastomosed to the subclavian artery and the other is anastomosed to the pulmonary artery (Figure 22.15b). Heparin 1 mg (100 units)/kg is given prior to clamping the artery. After flushing out the air, the clamps are released. Bleeding from needle holes usually stops with gentle packing. The lung is then allowed to expand. There is usually an immediate rise in pulse oximetry readings. Care is taken to monitor the patient and look for signs of 'flooding' of the lungs in the postoperative period because of increased blood flow from the shunt. If this occurs and the patient develops congestive failure, the diameter of the shunt may be reduced or the shunt may even have to be taken down. Since this is a temporising procedure, regular follow-up and referral when possible is advisable.

Surgery for coarctation of the aorta

Coarctation of the aorta is a congenital defect where the aorta is narrowed. The most common site of coarctation is immediately distal to the origin of the left subclavian artery.

This condition results in hypertension of the upper limbs and occasionally patients present with complications of hypertension. Relief of the coarctation can be accomplished by a balloon plasty or through surgery.[34] In remote locations where interventional



22.16 (a) Coarctation of the aorta through left thoracotomy. A, recurrent laryngeal nerve; B, ligamentum arteriosum; C, descending thoracic aorta. (b) Repair with a patch. (c) End-to-end anastomosis after excising the narrowed segment. (Illustrated by Mahil Matthew Peter.) ⏎

cardiology services are not available, a surgical option even in neonates is effective.[35]

A left thoracotomy through the fourth intercostal space is performed with the patient in the right lateral position as described earlier. The left lung is collapsed (when a double-lumen tube is used) or retracted anteriorly. This exposes the aorta and the left subclavian artery. The anatomy around the origin of the subclavian artery, the coarctation and the descending thoracic aorta are dissected and delineated (Figure 22.16a).

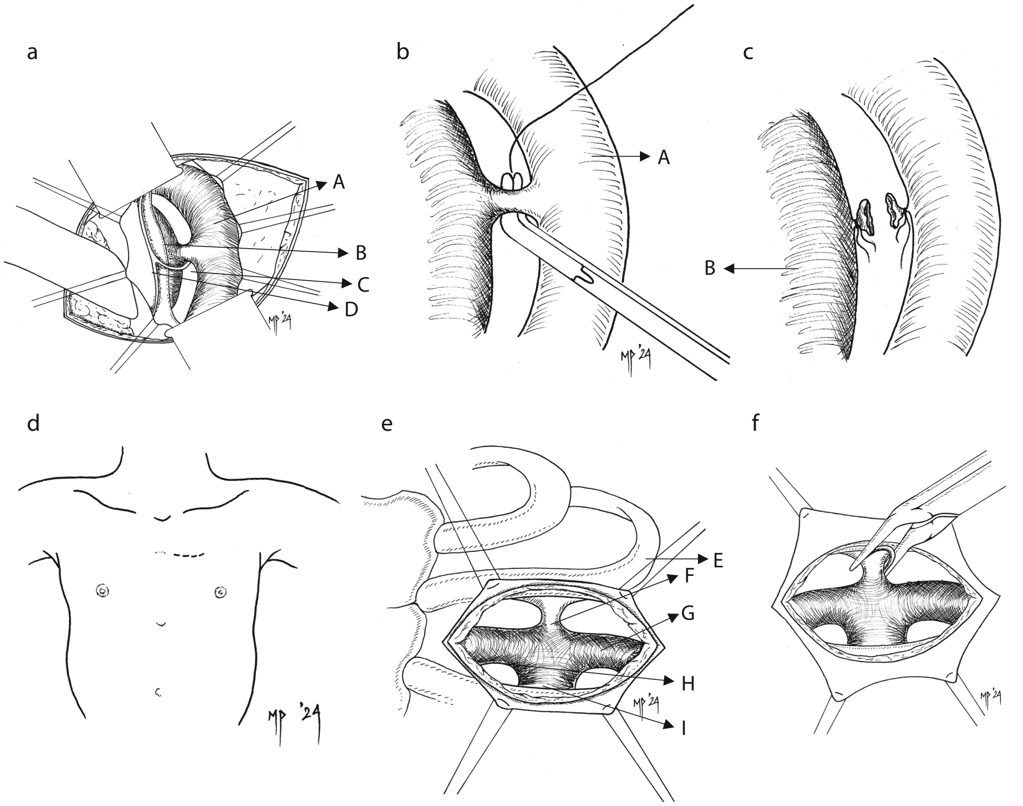
After coordinating with the anaesthetist, systemic heparinisation (1 mg/kg) is infused and the blood pressure is reduced before applying a cross-clamp to the aorta above and below the coarctation. It may be necessary to clamp proximal to the subclavian artery and clamp the subclavian artery separately. Either a patch aortoplasty (Figure 22.16b) or an end-to-end reconstruction (Figure 22.16c) is performed. It is essential to keep the cross-clamp time to a minimum to avoid renal, intestinal and neurological complications. Bleeding from needle holes is usually controlled with light packing and reversal of heparin with protamine.

Surgical closure of a patent ductus arteriosus

When the ductus arteriosus, an essential connection between the pulmonary artery and the aorta during fetal life, fails to close spontaneously after birth, the condition is called patent ductus arteriosus (PDA). Closure can be accomplished by an interventional cardiology team with occluding devices and coils. In some situations, even in the neonatal period, this condition can lead to heart failure. Closure of the PDA is the only chance of survival and can be accomplished in the neonatal intensive care unit.[36,37]

A left thoracotomy in the fourth intercostal space is performed and the left lung is retracted anteriorly, which exposes the distal arch, left subclavian artery, descending aorta and PDA. Dissection is carefully carried out to delineate the aorta and the PDA (Figure 22.17a). The PDA is encircled using a right-angled clamp and a tape is passed (Figure 22.17b). In children, the PDA can be divided between two or three ligatures (Figure 22.17c). In older patients, the PDA can be divided between clamps and both ends closed with fine 5/0 or 6/0 monofilament Prolene sutures.

In neonates, PDA closure can be accomplished in the intensive care unit through an anterior mini-thoracotomy and clipping of the PDA. A small incision is made parallel to the rib in the second intercostal space anteriorly extending to the left of the sternum (Figure 22.17d). Dissection beyond the intercostal muscles reveals the pulmonary artery and the PDA (Figure 22.17e). The PDA is then encircled and ligated or clipped (Figure 22.17f). This approach obviates the need for a chest tube.



22.17 (a) PDA through a left thoracotomy. A, aorta; B, pulmonary artery; C, PDA; D, recurrent laryngeal nerve. (b) PDA encircled with a right-angled clamp. (c) PDA cut and divided between ties or sutures. (d) PDA through anterior left subclavicular incision. Used in neonates. (e) Intrapericardial dissection. E, second rib; F, PDA; G, left pulmonary artery; H, right pulmonary artery; I, main pulmonary artery. (f) PDA clipped (may be ligated). (Illustrated by Mahil Matthew Peter.) ⏎

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23 Surgery of the neck

Emmanuel Lazarus

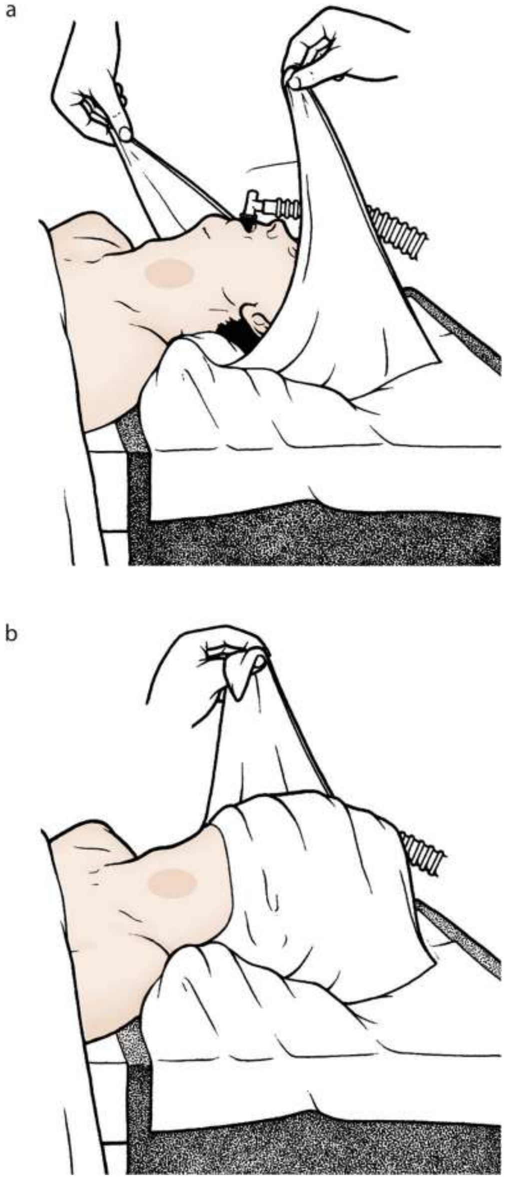
GENERAL TECHNIQUE

ANAESTHESIA AND PREPARATION

Local infiltrative anaesthesia is suitable for superficial surgery in the neck. General anaesthesia, with a laryngeal mask, is appropriate for most procedures, but longer operations, or procedures requiring movement of the head, are safer performed with endotracheal intubation. Cervical plexus blocks have proved to be both a safe and an effective alternative to general anaesthesia for carotid endarterectomy.

The positioning of sterile towels so that they do not slip during surgery is important. A well-established method is illustrated in Figure 23.1. The patient's head may then be turned to either side, or held straight, with the occiput resting within a ring or horseshoe support. Extension of the neck is achieved with a sandbag beneath the shoulders, and supraclavicular access is improved by traction on the arm.

Even relatively superficial neck surgery can result in troublesome haemorrhage from anterior jugular veins and their tributaries. A steep head-up tilt will reduce venous bleeding, but at the risk of air embolus from negative intravenous pressure. Any hole in a large vein must be immediately occluded by digital pressure and the anaesthetist warned of the possibility of entry of air into the circulation.



23.1 (a) The patient's head is lifted. A sterile waterproof paper sheet and two sterile towels are laid beneath the head and neck. (b) The uppermost towel is folded across, over the chin, to cover the face and the anaesthetic tubing. ⏎

NECK INCISIONS

Wounds in the neck can heal with disfiguring scars. Incisions must be planned, wherever possible, to follow the natural skin creases (or relaxed skin tension lines). These run approximately horizontally, and most incisions can be placed along them (Figure 23.2). When extensive longitudinal access is required, a vertical incision can often be avoided by making two separate transverse incisions (see Figure 23.8b), and this is particularly important anteriorly, where vertical scars

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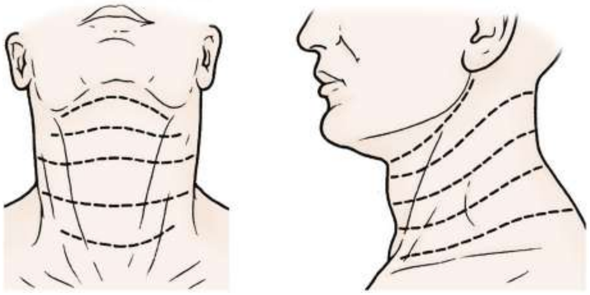


23.2 Relaxed skin tension lines in the neck are approximately horizontal. ⏎

will often hypertrophy and contract. Even a horizontal incision anteriorly will tend to hypertrophy in the suprasternal notch, and incisions for thyroid surgery should not be positioned too low for this reason.

If a vertical component to an incision is inevitable, it will cause less scarring if placed laterally, either along the anterior border of the sternocleidomastoid (see Figure 23.4b) or along the anterior border of the trapezius.

Postoperatively, a deep haematoma can threaten the airway due to tracheal compression. Vacuum drainage for 24–48 hours is favoured by many, but it is not a substitute for meticulous haemostasis. A superficial haematoma must also be avoided, as it can increase subcutaneous fibrosis and scarring. Accurate apposition of skin and platysma is important for a good cosmetic result. Platysma is sutured with absorbable sutures and provides considerable support to the skin closure. Skin clips, or interrupted skin sutures, can therefore usually be removed from the transverse anterior wounds used for thyroid surgery within 48 hours, without fear of wound dehiscence, although sutures in other neck wounds should normally be left for around 7 days.

TRAUMA

Closed trauma to the neck is dominated by forced flexion or extension injuries to the cervical spine and spinal cord. Mechanical protection of the cervical spine is essential until an unstable cervical fracture has been excluded. An intimal tear of a carotid artery can occasionally be caused by the same force. No neurological symptoms or signs should be dismissed, and preoperative arterial imaging should be considered in a stable but unconscious patient before exploration of non-vascular injuries. An anterior impact, or crushing injury to the neck, may inflict severe bruising and swelling, with progressive obstruction of the airway. Less commonly, a fracture is sustained to the skeleton of the larynx or the trachea is transected.

Penetrating and open trauma includes a wide range of injuries, from clean knife wounds to the extensive soft tissue damage seen in military conflict.[1] Penetrating neck injuries are those that penetrate platysmal integrity.[2] Stab injuries are common in cities where there is a high incidence of urban violence. Guns are increasingly replacing knives and, in some areas, are the most common cause of penetrating neck trauma. In assaults, traffic accidents and falls from a great height, penetrating and forced flexion–extension injuries can coexist.

SURGICAL MANAGEMENT OF NECK TRAUMA

Knowledge of the mechanism of injury is important in the assessment. Even in an open injury, the possibility of an unstable cervical fracture may have to be considered, even though mechanical protection of the spine will make assessment of the injury, control of haemorrhage and maintenance of the airway more difficult. The initial management is guided by Advanced Trauma Life Support (ATLS) principles. The presence of 'hard' signs – shock, airway compromise, stridor, neurological deficits, pulsatile bleeding or an expanding haematoma, air bubbling from the wound, a palpable thrill or an audible bruit, feeble pulses or massive subcutaneous emphysema – suggests major vascular or aerodigestive tract injuries and these warrant exploration in the operating theatre.[2,3]

Establishment of a secure airway is the first priority. Endotracheal intubation is essential in any patient with neck trauma who is unconscious or who has respiratory difficulty. The cuffed tube also protects the lower respiratory tract from further inhalation of blood. If endotracheal intubation is not possible, an emergency tracheostomy may be required. A cricothyroidotomy may be a faster alternative in an emergency.

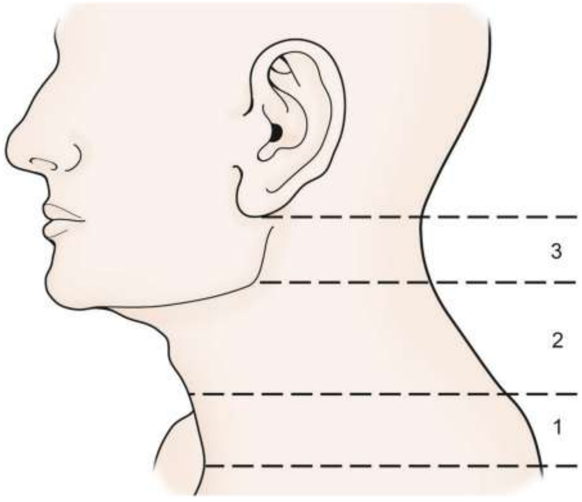
Arrest of haemorrhage is the next priority. External haemorrhage can usually be controlled by direct pressure until a wound is explored. Haemorrhage into the pharynx may be profuse, but once the airway is secure, either with an endotracheal tube or with a tracheotomy, pressure on the bleeding areas with pharyngeal packing will often bring the haemorrhage under control. The soft tissue of the neck is supplied almost entirely from branches of the external carotid artery. On rare occasions, emergency ligation of an external carotid artery may be life saving. Clear confirmation of an intact internal carotid artery is mandatory. The emergency surgical approach is through an incision along the anterior border of the sternocleidomastoid. The external carotid is usually the more anterior division and has branches. However, the carotid bifurcation may be distorted by trauma and haematoma. Spasm, particularly in a young patient, means that the calibre of a vessel is no guide to its importance or identity. If a vessel has to be clamped before exploration is complete, it must be done with a view to the possible need for repair or replacement.

The haemodynamically stable patient without hard signs, but with suspicion of injury, should be evaluated with computed tomography (CT) angiography with further evaluation based on the clinical and radiological findings.[2] Recently, a 'no-zone' approach to neck trauma has been advocated to reduce negative neck exploration rates with the decision to operate based on haemodynamic stability and the presence of 'hard signs'.[4,5]

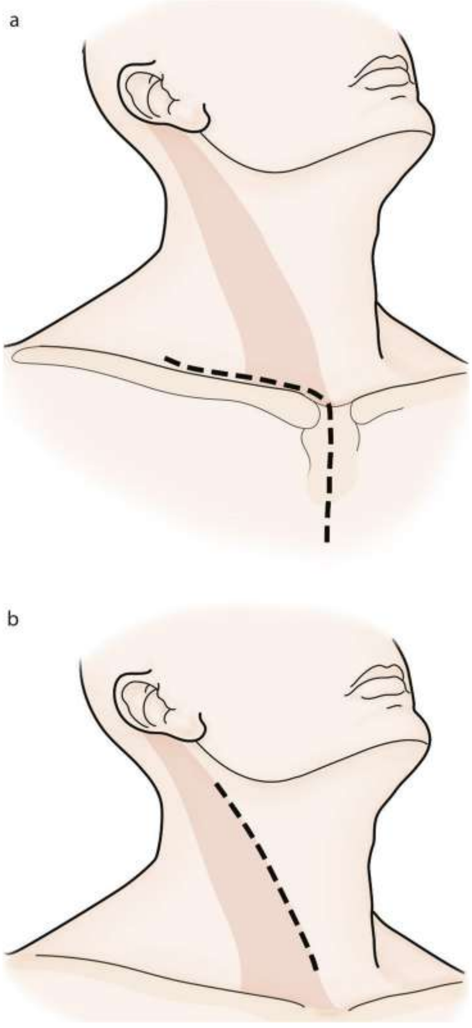
Vascular injuries

The neck is divided into three zones for the management of trauma in relationship to possible vascular injury (Figure 23.3). Wounds in zone 1 may have involved the major vessels in the superior mediastinum, and any exploration of such a wound will almost certainly require simultaneous access to the neck and mediastinum, with a supraclavicular incision extended down as a median sternotomy (Figure 23.4a). A widened mediastinum on chest X-ray will alert the surgeon to a severe injury and an angiogram should be performed before exploration unless haemorrhage forces immediate surgery. If at all possible, surgery should be undertaken by an experienced vascular or cardiothoracic surgeon (see Chapters 18 and 22). The potential help from an interventional radiologist, if available, should be remembered, as placement of a balloon into one of the major arch vessels may be sufficient to control haemorrhage and allow direct surgical repair.

Stab and bullet wounds are most commonly situated in zone 2 and the risk of major vascular damage is higher for lateral wounds. Some surgeons recommend exploration for all laterally placed zone 2 injuries. If a selective policy is followed, exploration should be undertaken of any lateral wound with evidence of significant haemorrhage. Preoperative angiography is not routinely recommended in an unstable or actively bleeding patient. Good access is essential, and an oblique vertical incision along the anterior border of the sternocleidomastoid will provide the best arterial and venous exposure (Figure 23.4b).



23.3 Zone 1 extends for 1 cm above the upper border of the manubrium; zone 3 is above the angle of the mandible; zone 2 lies in between. ⏎



23.4 (a) Zone 1 injuries to the carotid artery may require simultaneous access to the superior mediastinum. A median sternotomy incision can be extended as a supraclavicular incision or as an incision along the anterior border of the sternocleidomastoid. (b) The incision along the anterior border of the sternocleidomastoid gives the best access to the carotid artery in an emergency. ⏎

A transverse incision can also be used. This allows access to both sides of the neck and can be extended vertically along the sternocleidomastoid anterior border as needed.

A clean incision into a carotid artery can be sutured, but more frequently a vein patch is more appropriate to prevent stenosis (see Chapter 18). Consideration should be given to a temporary intraluminal shunt to preserve cerebral perfusion and, if the internal carotid is injured, this is essential. Stroke is a significant possibility even in a young patient with no other arterial disease. A common carotid injury, which can be isolated with clamps below the bifurcation, does not always require a shunt, as retrograde external carotid flow will perfuse the intracranial carotid territory. An injured internal jugular vein can be ligated without adverse effect if the contralateral internal jugular is patent.

Penetrating wounds in zone 3 are directly over the internal carotid artery. Access is difficult and simultaneous access intracranially may be necessary. A preoperative angiogram, together with the involvement of a vascular specialist and, occasionally, also a neurosurgical specialist is important. Venous injuries in particular may extend up to the base of the skull. Venous bleeding will be torrential, as the vessel is held open at the jugular foramen. If a Fogarty catheter is inserted into the foramen, the inflated balloon can control haemorrhage while a purse-string suture is inserted.

Laryngeal, tracheal and oesophageal injuries

Blunt trauma, with resultant haematoma and oedema, may obstruct the airway and, in a severe crushing injury, there may be fractures of the skeleton of the larynx. Blunt trauma can usually be treated conservatively and any threat to the airway managed by tracheotomy. Laryngeal injury is best assessed on CT scanning. A fractured hyoid is usually managed conservatively, but a thyroid cartilage fracture, with displacement, often requires repair with wires or mini-plates. A history of anterior impact associated with emphysema requires bronchoscopy to exclude a transected trachea, as sudden asphyxia can occur if the divided ends become displaced. Formal repair is indicated for this injury.

Penetrating injuries will often heal spontaneously. A selective policy for exploration has generally been adopted since it was shown to be safe to explore only wounds through which air was bubbling or those that were associated with major haemoptysis or haematemesis.[6] All other patients with emphysema, and patients in whom there is another reason to suspect injury, are managed conservatively with prophylactic antibiotics and a nil-by-mouth policy until a contrast study has excluded an oesophageal leak. If a leak is demonstrated, oral intake must await a repeat contrast study to show that the leak has sealed. Further assessment of a tracheal injury includes laryngoscopy and bronchoscopy.

When repair is indicated, access to the superficial larynx and trachea is relatively straightforward. Simple closure, after wound debridement, with interrupted absorbable sutures is generally satisfactory. Access to the deeply placed pharynx and cervical oesophagus is difficult, especially when the anatomy is distorted by haematoma. The approaches described below for drainage of retropharyngeal and parapharyngeal abscesses can be used, but a surgeon with limited experience in the neck will be reluctant to attempt any formal repair. Fortunately, arrest of haemorrhage, drainage of the parapharyngeal space and a strict nil-by-mouth policy until the breach has healed will often suffice.

Nerve injuries

Any penetrating injury to the neck may have severed a nerve. Optimum operative conditions and surgical skill are more important than timing in repair, and referral to the relevant specialist is important (see Chapter 24).

INFECTIONS

Cellulitis in the neck requires prompt treatment with antibiotics. Careful monitoring of the airway is important, as a tracheotomy may occasionally become necessary. Any abscess should be drained. The underlying pathology must be sought, as this may require surgical attention. Contamination from a breach in the wall of the hypopharynx, or the cervical oesophagus, should be suspected in any patient who has had recent cervical trauma or surgery.

Abscesses can occur in any of the fascial spaces in the neck. The infection may be a direct extension of a primary infective process or secondary to a suppurative lymphadenitis in the drainage nodes. *A peritonsillar abscess* (quinsy), the combined *submental and submandibular abscess* (Ludwig's angina) and pyogenic *retropharyngeal abscesses* present intraorally and are considered in Chapter 4B.

RETROPHARYNGEAL ABSCESS

The retropharyngeal space lies between the pharynx and the posterior layer of the deep fascia and extends from the base of the skull to the level of the tracheal bifurcation in the posterior mediastinum. In the adult, retropharyngeal abscesses are usually tuberculous, secondary to cervical spine involvement. In contrast with pyogenic retropharyngeal abscesses in the child, which are drained into the oropharynx (see Chapter 4B), the tuberculous pus should be drained to the exterior. A horizontal incision is made, one finger breadth below the angle of the jaw. The tail of the parotid gland is dissected from the sternocleidomastoid, which is then retracted. The carotid sheath is retracted posteriorly. The superior constrictor is then identified and, by passing a finger lateral and posterior to the pharynx, the retropharyngeal space can be entered. Locules are broken down, the pus evacuated and a drain left in the cavity.

PARAPHARYNGEAL ABSCESS

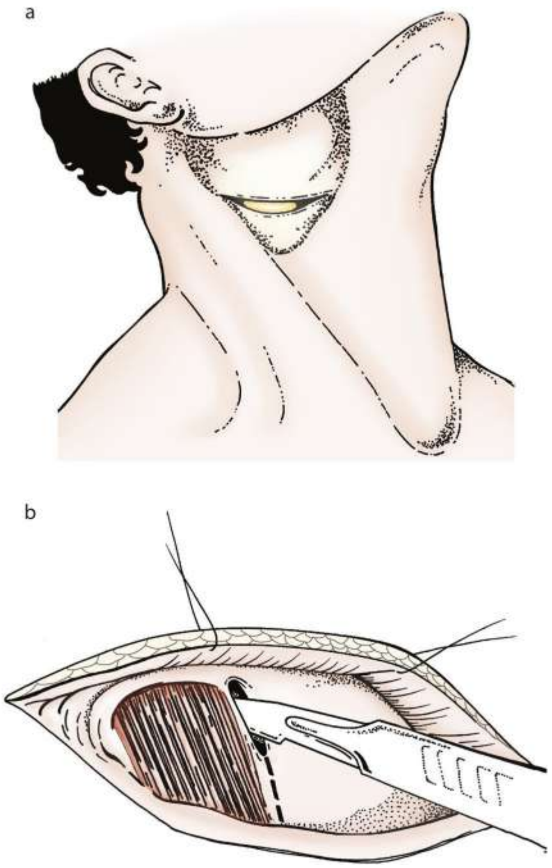
The parapharyngeal space lies lateral to the pharynx. It is bounded laterally by the lateral pterygoid muscle and the parotid gland. It extends from the base of the skull to the level of the hyoid bone, where it is limited by the fascia over the submandibular gland. The carotid sheath lies posteriorly. An abscess in this space may be associated with a tonsillar infection and a quinsy, or with an infected lower third molar tooth. The primary pathology should be addressed first. However, drainage of pus will probably still be inadequate, and direct drainage of the parapharyngeal space may still be required. A horizontal incision is made over the anterior border of the sternocleidomastoid, two finger breadths below the jaw. The sternocleidomastoid muscle is retracted posteriorly and the deep cervical fascia is incised to enter the abscess cavity (Figure 23.5). This abscess is deep and often multiloculated and is best explored with blunt finger dissection. It will also require a drain left *in situ* after initial drainage.

ACUTE MASTOIDITIS

Acute mastoiditis is discussed in Chapter 4B.

ACUTE PAROTITIS

This once common complication in the postoperative surgical patient is now a rarity. It is associated with poor hydration, nutrition and mouth hygiene. In the early stages, it may resolve on antibiotic therapy but, once pus has formed, it must be drained. A small transverse incision, to minimise any risk to the branches of the facial nerve, is made overlying the area of greatest swelling. It is deepened until pus is encountered. Fortunately, the abscess usually occurs in the superficial portion of the gland and the facial nerve is safe, lying deep to the abscess cavity.



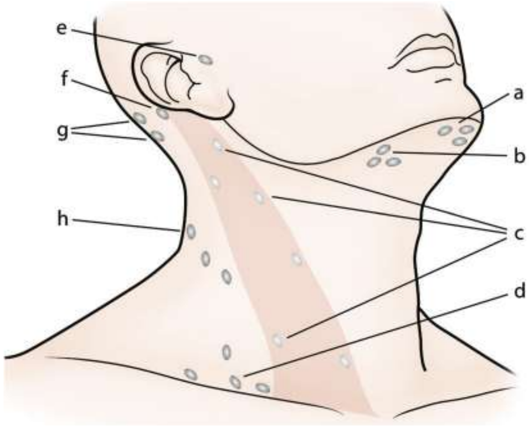
23.5 (a) The skin incision for drainage of a parapharyngeal abscess. (b) The deep cervical fascia is incised at the anterior border of the sternocleidomastoid and the abscess is entered. This approach is also used for access to the deep lymphatic tissue of the neck and for access to the upper oesophagus and hypopharynx. ⏎

SURGERY OF LYMPH NODES

SURGICAL ANATOMY

The lymph nodes of the neck are somewhat arbitrarily divided into groups, which are then described according to the position in which they lie (Figure 23.6):

- *Submental* and *submandibular nodes* drain the floor of the mouth and the tongue. These nodes are described as level I cervical nodes.
- *Deep cervical nodes* lie deep to the sternocleidomastoid muscle and the deep cervical fascia. They lie both outside and within the carotid sheath, in contact with the internal jugular vein. They drain the tonsil, the pharynx, the larynx, the trachea and the thyroid gland. Therefore, inflammation in these nodes is more common with upper respiratory infections, and carcinoma of the pharynx, larynx or thyroid may present with an enlarged metastatic node in the deep cervical group. Nodes



23.6 The cervical lymph nodes. a, submental; b, submandibular; c, deep cervical; d, supraclavicular; e, preauricular; f, mastoid; g, occipital; h, posterior triangle. ⏎

are categorised into level II, III and IV cervical nodes, representing the upper, middle and lower nodes of this group, respectively.

- *Preauricular*, *mastoid* and *occipital nodes* are superficial nodes that drain the skin and superficial tissue of the face and scalp.
- The *posterior triangle nodes* are deep to the investing fascia. They are classified as level V nodes.
- *Supraclavicular nodes* are continuous with the superior mediastinal nodes and with the axillary nodes. Metastatic involvement is seen in breast, bronchial and upper gastrointestinal cancer. Supraclavicular nodes are also classified as level V cervical nodes.
- *Anterior compartment nodes* surround the midline visceral structures and include the retropharyngeal, paratracheal, pre-laryngeal and pre-tracheal nodes. They are classified as the level VI group.

DRAINAGE OF PURULENT LYMPHADENITIS

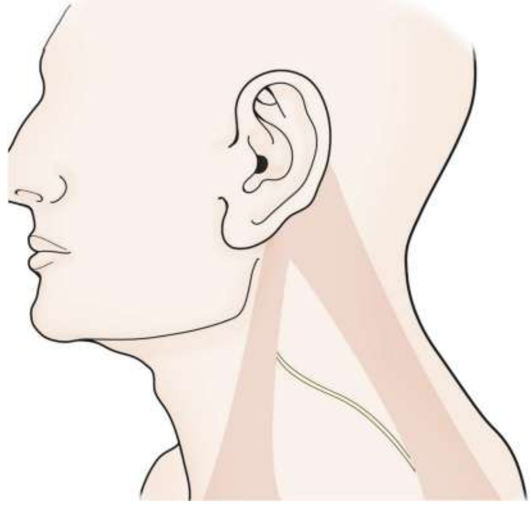
Purulent lymphadenitis can occur secondary to a tonsillitis or other upper respiratory tract infection and is encountered most frequently in infants. The upper deep cervical chain is the most commonly involved but, by the time it is apparent that there is pus and that the infection will not resolve with antibiotics, there is simply a collection of pus laterally in the neck, which must be drained. A formal dissection with identification of the sternocleidomastoid and incision of the deep fascia to enter the deeper planes is seldom necessary. A small transverse incision over the most prominent part of the swelling, which is then deepened until pus drains, is normally sufficient. This incision will leave a satisfactory scar but will provide inadequate continuing drainage unless a drain is placed into the depth of the abscess cavity and sutured to the skin.

DIAGNOSTIC LYMPH NODE BIOPSY

The differential diagnosis of an enlarged cervical lymph node includes inflammation, lymphoma and metastatic malignancy. Up to one in five patients with a carcinoma of the nasopharynx, oral cavity, oropharynx, larynx or hypopharynx presents with a nodal metastasis. Such nodes should be excised *en bloc* with the other drainage nodes and the primary malignancy, to maximise the chance of cure. Nodal biopsy in isolation for diagnosis should be avoided, as there is evidence that this increases morbidity and possibly decreases long-term survival in patients with squamous carcinoma. A general surgeon who sees a patient with an isolated neck node, particularly in the submandibular area or in the deep cervical chains, should look for a primary lesion in the drainage site. An ear, nose and throat (ENT) specialist opinion for a naso-pharyngolaryngoscopy is also important prior to biopsy, so that malignancy within the drainage area can be excluded. The position of the enlarged node is a guide to the site of the primary pathology.[7] Thyroid cancer can also present with a cervical node metastasis, but in thyroid cancer an initial excision of a malignant node does not so adversely affect prognosis. Malignant supraclavicular nodes are usually associated with advanced malignancies, often from a primary cancer in the breast, chest or abdomen, which is no longer surgically curable. Isolated excision biopsy is therefore oncologically harmless.

Fine needle aspiration may be sufficient to confirm metastatic cancer cells, but often the specimen obtained cannot differentiate between inflammatory and lymphomatous changes, for which a node biopsy is necessary. The pathologist must be able to study the architecture of the gland and, ideally, a whole node is excised with the dissection on the capsule of the node. If this is not possible due to the proximity of vital structures or when nodes are matted together, a generous wedge excision is a safe compromise.

Occipital and *posterior triangle nodes* are relatively superficial with no large vessels nearby. Local anaesthesia is therefore suitable. However, the operation should not be underestimated or undertaken for insignificant nodes. The surgeon must be aware of the surface markings of the accessory nerve when removing level V nodes, as the nerve crosses the posterior triangle at the level of the deep fascia (Figure 23.7). The nodes lie in close proximity to the nerve, which is thus extremely vulnerable to injury from either surgical division or diathermy damage. Accessory nerve injury results in significant shoulder dysfunction.



23.7 The accessory nerve crosses the posterior triangle at the level of the deep fascia. The surface markings are from the junction of the upper and middle third of the sternocleidomastoid to the junction of the middle and lower third of the trapezius. Level Va occipital lymph nodes lie in close proximity to the nerve. ⏎

Deep cervical nodes are deep to the sternocleidomastoid, and surgery under general anaesthesia and a protected airway are recommended. A transverse incision through skin and platysma, followed by posterior retraction of the sternocleidomastoid muscle after incision of the deep cervical fascia along its anterior border, will provide access into the correct plane. Care must be taken not to damage the internal jugular vein; its anterior tributaries, such as facial and thyroid veins, may have to be ligated and divided.

Supraclavicular nodes are often deceptive and found at operation to be deeper than initially suspected. They may be 'the tip of the iceberg' and be the accessible part of a mass of matted mediastinal nodes, which are compressing the trachea and distorting the anatomy of the great vessels at the root of the neck. The surgeon should dissect with caution under optimum surgical and anaesthetic conditions. Tracheal compression in the superior mediastinum can make a general anaesthetic hazardous, but this is also a hazardous area for a surgeon to operate under local anaesthesia.

NECK DISSECTION

The classical *radical neck dissection* described by Crile in 1906 included the *en bloc* excision of all cervical lymph nodes along with the sternocleidomastoid muscle, the internal jugular vein and the accessory nerve.[8] Most surgeons now prefer to preserve some of these non-lymphatic structures, even in the neck dissections for head and neck malignancies. Preservation of function in the accessory nerve is particularly desirable. Such dissections are described as *modified radical neck dissections*, and these are classified as:

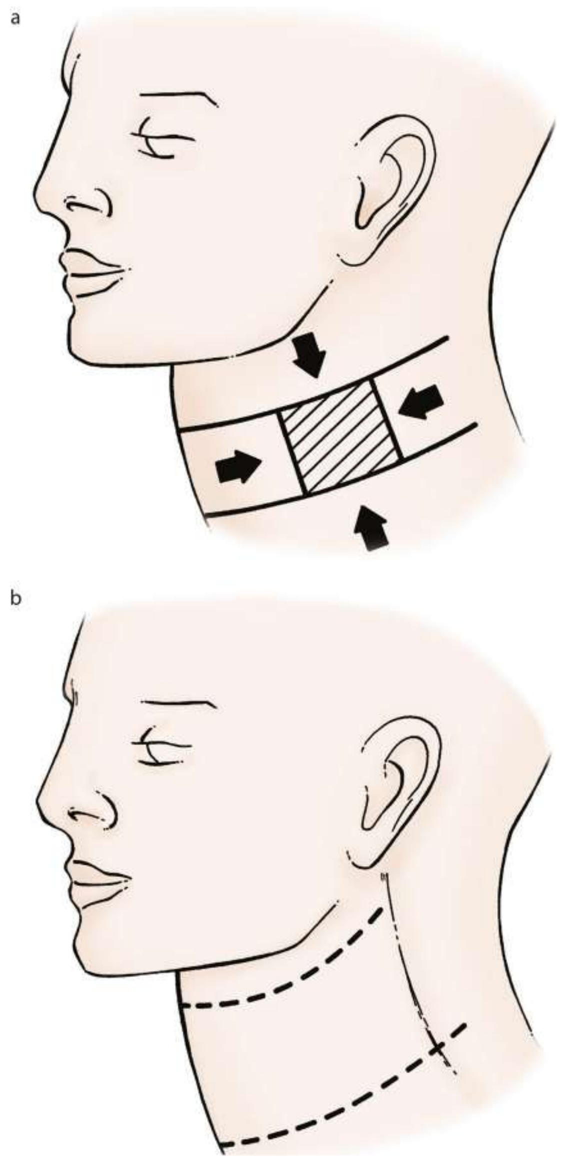
- *Type I*, with preservation of the accessory nerve
- *Type II*, with preservation of the accessory nerve and the internal jugular vein
- *Type III*, with preservation of the accessory nerve, internal jugular vein and sternocleidomastoid

A *selective neck node dissection* preserves one or more lymph node groups in addition to the three non-lymphatic structures. For example, a level VI selective dissection is employed commonly in thyroid cancer.

The incisions for any form of radical neck dissection must be planned to afford good access and leave inconspicuous scars. In addition, skin viability must be preserved, as a carotid artery exposed by skin breakdown has a risk of rupture. The blood supply to the skin of the lateral neck comes from all directions, with a resultant relatively poorly vascularised central area directly over the common carotid artery (Figure 23.8a). Vertical incisions and three-point junctions in this central area should therefore be avoided, especially when radiotherapy has already been used and salvage surgery is being undertaken. Suitable incisions for radical neck dissections are shown in Figure 23.8b.

The skin flaps are elevated to include the platysma. In the submandibular area, in order to preserve the marginal mandibular branch of the facial nerve, the nerve is formally identified. If this is difficult, the flaps should be elevated by dissection in a deeper plane. This plane is on the body of the submandibular gland, and the fascia over the gland is included in the elevated flap.

Inferiorly, the sternal and clavicular heads of the sternocleidomastoid are divided to expose the carotid sheath. The internal jugular vein is isolated by dissection around the vein, and the vagus nerve, which lies in a deep plane between the vein and the common carotid artery, is identified and preserved. The vein is then divided between ligatures. On the left, the thoracic duct is commonly divided at this point and will require oversewing to prevent leakage. The dissection is continued laterally, above the prevertebral fascia, to the anterior border of the trapezius, elevating the fat pad overlying the scalene muscles and dividing the inferior belly of the omohyoid muscle, which is included in the specimen. The external jugular vein and supraclavicular cutaneous nerves must also be divided. The transverse cervical vessels lie between the fat pad and the prevertebral fascia and should, if possible, be preserved. Underneath the prevertebral fascia, the phrenic nerve runs medially and



23.8 (a) The shaded area has the poorest blood supply in the neck. It also overlies a relatively superficial segment of the carotid arteries. (b) Incisions that afford excellent exposure but avoid vertical incisions or three-point junctions in this area of skin. ⏎

downwards on the scalenus anterior. It is identified and preserved. The trunks of the brachial plexus are also beneath this fascia. Bipolar diathermy is therefore preferable to monopolar diathermy for this dissection so close to the nerves.

Posteriorly, the limit of dissection is the trapezius, and the dissection is continued up along its anterior border (Figure 23.9a). The transverse cervical artery gives a vertical branch, which runs up the anterior border of the trapezius and requires formal ligation and division. The accessory nerve is divided in the classical radical dissection as it enters the muscle, but is preserved in all modified neck dissections. The upper third of the trapezius approaches the posterior border of the sternocleidomastoid muscle, the fibres of which are divided close to their mastoid insertion.

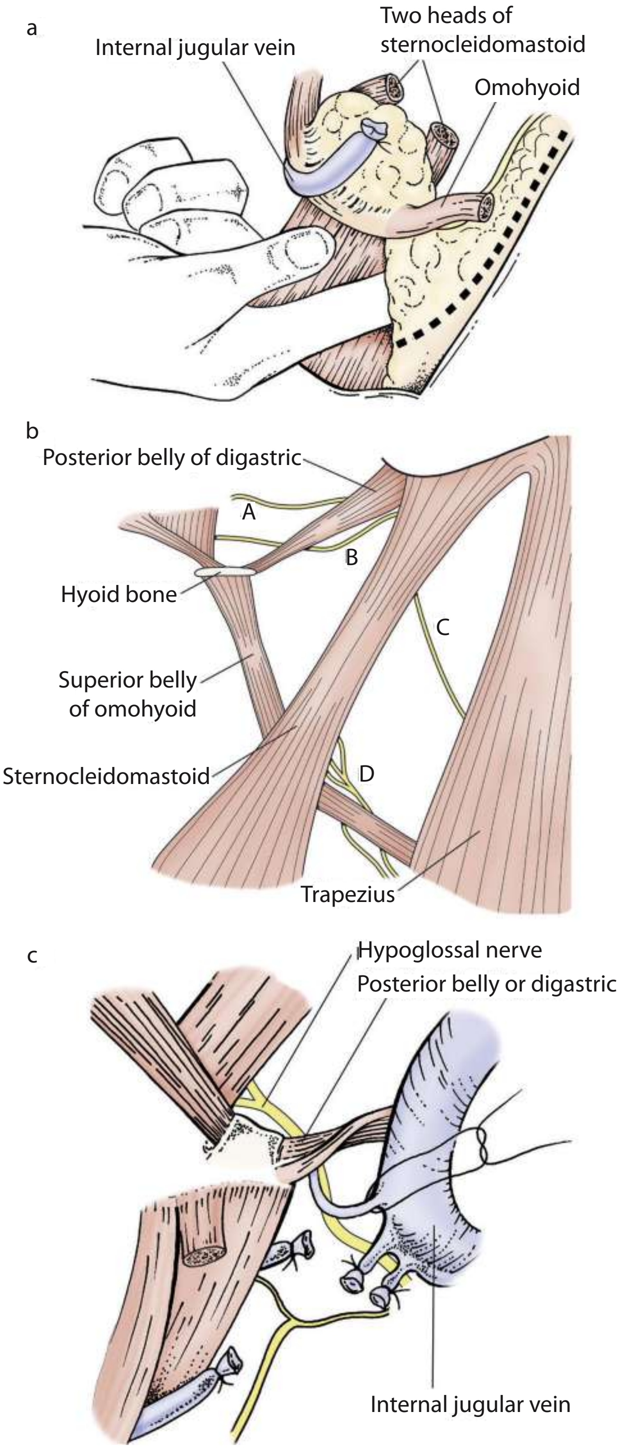
Anteriorly, the superior belly of the omohyoid muscle forms the boundary of the dissection and is followed to its insertion into the hyoid bone and divided (Figure 23.9b). The submental fat pad is dissected off until the anterior bellies of both digastric muscles are identified.

The *deep dissection* is commenced by reflecting forwards the posterior margin of the dissection and releasing the fat pad, with the nodes, off the prevertebral fascia and the underlying muscles, the levator scapulae and the scalenes. The specimen is tethered by the four cutaneous branches of the cervical plexus, namely the transverse cervical, the greater auricular, the supraclavicular and the lesser occipital nerves. These nerves are identified and divided well away from the phrenic nerve. The internal jugular vein is dissected out of the carotid sheath up to the jugular foramen. The transverse process of the atlas is palpated and, just above this, the posterior belly of the digastric will be found. This is retracted upwards and the upper end of the jugular vein is exposed, where it is again divided between ligatures, with care being taken to preserve the vagus nerve. The hypoglossal nerve can be seen crossing lateral to the external carotid artery, and is in turn crossed by three small veins draining from the tissue to be excised. These vessels must be ligated and divided or they will tear, and attempts to stop the bleeding will endanger the hypoglossal nerve (Figure 23.9c). The remaining sternocleidomastoid fibres are divided at the level of a line extending from the tip of the mastoid process to the angle of the jaw. A higher division places the facial nerve at risk, as it lies deep to the anterior border of the muscle.

Superiorly, the submental fat pad and the anterior edge of the submandibular gland are dissected off the lateral surface of the mylohyoid muscle. The submental artery will require ligation and division. The posterior edge of mylohyoid is then retracted forwards and the gland retracted inferiorly to expose the lingual nerve, which is freed and preserved. The submandibular duct is ligated. The facial vessels are ligated at the upper border of the gland and the facial artery again at the inferior border.

Complications

Immediate complications include haemorrhage, pneumothorax and raised intracranial pressure from compromised venous drainage. Necrosis of skin flaps, with exposure of the carotid artery, is a serious intermediate-term complication that requires further surgery at the earliest opportunity to cover the vulnerable vessel. A chylous fistula from injury to the thoracic duct is initially treated conservatively, but


a
Internal jugular vein
Two heads of sternocleidomastoid
Omohyoid
b
Posterior belly of digastric
A
B
Hyoid bone
C
Superior belly of omohyoid
Sternocleidomastoid
D
Trapezius
c
Hypoglossal nerve
Posterior belly or digastric
Internal jugular vein

23.9 Radical neck dissection on the left. (a) The fat pad with the divided inferior belly of the omohyoid, the two heads of the sternocleidomastoid and the internal jugular vein are turned up. The surgeon's finger is on the scalenus anterior and the incision will next be extended up the anterior border of the trapezius along the dotted line. (b) The muscles that form the landmarks for a radical neck dissection are shown with some of the nerves. **A**, marginal mandibular branch of the facial; **B**, hypoglossal; **C**, accessory; **D**, brachial plexus. The superficial nerves have been omitted and the phrenic nerve is hidden by the sternocleidomastoid. (c) At the upper limit of the dissection, the hypoglossal nerve is vulnerable. The small veins that cross the nerve require individual ligation and division. ⏎

occasionally may require surgical intervention (see Chapter 9). Shoulder dysfunction is inevitable if the accessory nerve has been sacrificed.

TUBERCULOUS CERVICAL LYMPHADENITIS

This condition is still encountered where bovine tuberculosis is common. Untreated nodes caseate and discharge. Cold abscesses with adherent overlying skin proceed to chronic discharging sinuses and severe scarring. Surgery is seldom indicated if anti-tuberculous treatment is effective, although limited surgery in conjunction with effective anti-tubercular chemotherapy is sometimes appropriate. However, the emergence of multi-resistant strains means that, once again, the surgeon may have to operate on a tubercular abscess when no other treatment is effective. Tuberculous cervical lymphadenitis is almost invariably unilateral, and 90% of the abscess involves only one group of glands, the most common being the deep nodes beneath the sternocleidomastoid muscle, followed by the submandibular group.

When surgery is undertaken for resistant disease, it must include excision of all diseased nodes if it is to offer a reasonable chance of eradication of the infection. This can, however, be a challenging operation when the deep cervical nodes are matted and adherent to the internal jugular vein, the wall of which may form the medial wall of the tuberculous abscess. The peri-adenitis also significantly distorts tissue planes. CT imaging is useful for operative planning and can identify deeper collections that may not be clinically apparent. A dissection similar to the radical neck dissection described above may be necessary to secure the internal jugular vein above, and below, the segment of involved vein, which has to be removed *en bloc* with the specimen. The accessory nerve and the sternocleidomastoid muscle can usually be preserved.

CYSTIC HYGROMA

These are congenital cystic abnormalities of the cervical lymph vessels and may be so large that they cause obstruction to labour at birth or compress and obstruct the newborn's airway. The urgency of surgery will depend on size, but specialist referral is appropriate. Large lesions may extend down into the superior mediastinum and the deeper aspects may have to be dissected off the internal jugular vein. Superiorly, the multiloculated cyst may extend into the parapharyngeal space and the floor of the mouth. Dissection of the superior extensions places the facial nerve at risk, and a formal superficial parotidectomy may be necessary to safeguard its branches. Staged surgery or repeat resections are often necessary.

THE THYROID AND PARATHYROID GLANDS

SURGICAL ANATOMY

Thyroid gland

The thyroid lies in the lower part of the front of the neck as a bilobed gland joined by an isthmus that overlies the second to fourth rings of the trachea. The lobes lie lateral to the larynx and the trachea and are in close apposition to both. A gland of normal size extends from the middle of the thyroid cartilage to just above the clavicle. The gland is enclosed in a sheath of pre-tracheal fascia, so that it moves on swallowing. Superficially, it is covered by the sternothyroid and sternohyoid strap muscles.

Blood supply The thyroid gland's blood supply is from the superior and inferior thyroid arteries. The *superior thyroid artery* is the first anterior branch of the external carotid artery. It passes down to the upper pole of the thyroid lobe. The *inferior thyroid artery* arises from the thyrocervical trunk, a branch of the subclavian artery. It runs upwards and medially behind the carotid sheath to enter the middle of the back of the lobe. The *superior thyroid vein* leaves the gland with the superior thyroid artery and drains into the internal jugular or facial vein. The *middle thyroid veins* emerge from the lateral aspect of the lobe and cross in front of the common carotid artery to join the jugular vein. The *inferior thyroid veins* emerge from the isthmus and lower medial part of the lobe and descend in front of the trachea to end in the left brachiocephalic vein.

Regional nerves These nerves are in danger in any operation on the thyroid or parathyroid glands. The *external laryngeal nerve*, which is a terminal branch of the superior laryngeal branch of the vagus, runs downwards on the inferior pharyngeal constrictor, deep and medial to the upper pole of the thyroid gland, to end by supplying the cricothyroid muscle. Near its termination, the external laryngeal nerve is in close proximity to the superior thyroid artery and is vulnerable when this vessel is ligated. The recurrent laryngeal nerve supplies all the intrinsic muscles of the larynx. The recurrent laryngeal nerve arises from the vagus on the right side as it crosses the subclavian artery and on the left as it crosses the aorta. It hooks around the artery and ascends in the groove between the trachea and the oesophagus. It enters the larynx below the lower border of the inferior constrictor and is closely related here to the termination of the inferior thyroid artery, where it is vulnerable when this vessel is ligated. Anatomical anomalies, more common on the right, include a nerve following a more lateral course, which then runs obliquely or even horizontally towards the larynx alongside, or anterior to, the inferior thyroid artery and is therefore more vulnerable to injury.

Parathyroid glands

The parathyroid glands consist of bilateral superior and inferior glands that lie behind the thyroid. Each is ellipsoid and pea-sized and of a reddish-brown colour. Considerable variation in position is common, but classically the glands lie within 1–2 cm of the intersection of the recurrent laryngeal nerve and the inferior thyroid artery. The *superior glands* lie above and behind the nerve. The *inferior glands* lie below and in front of the nerve.

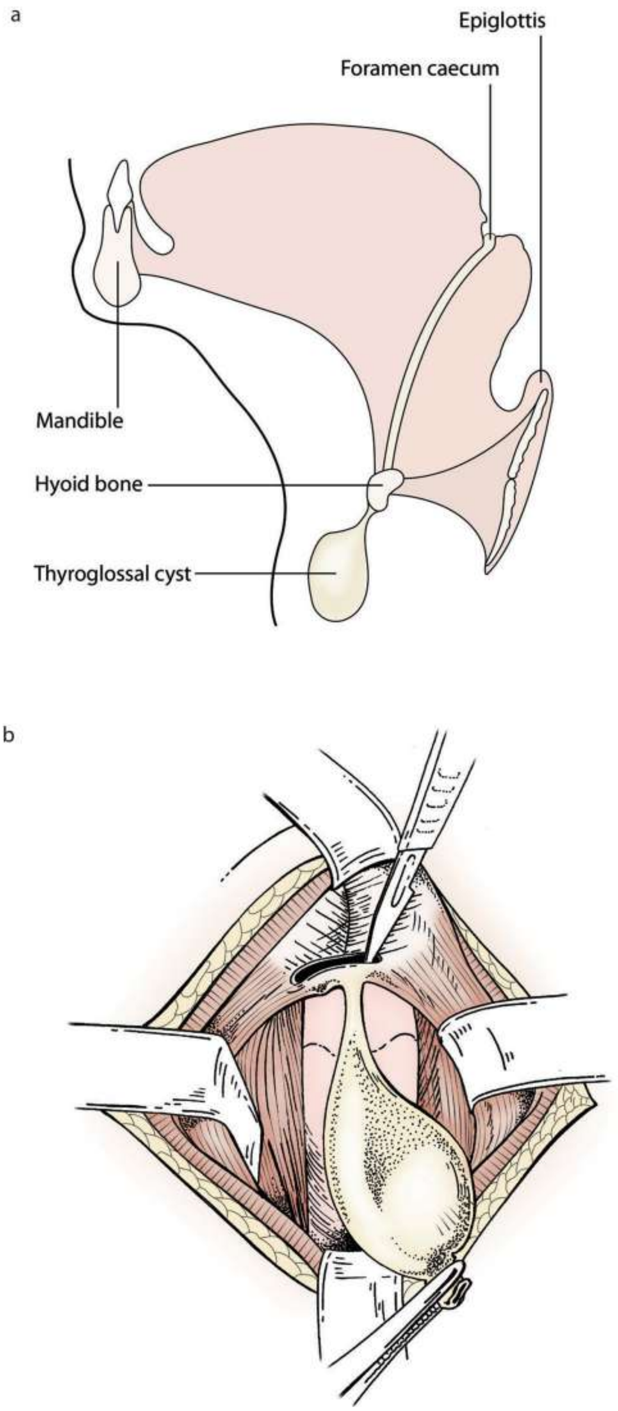
THYROID AND PARATHYROID SURGERY

A secure airway and good access for the surgeon are essential. These are usually achieved by a general anaesthetic with endotracheal intubation and the head towelling technique shown in Figure 23.1. The patient is positioned supine with a sandbag under the shoulders, the neck is extended and the occiput is supported on a head ring.

Excision of a thyroglossal cyst

The thyroid gland develops from the thyroglossal duct, which grows down from the foramen caecum at the junction of the middle and posterior third of the tongue. Incomplete regression of the duct results in a thyroglossal cyst or fistula. The cyst is in the midline, either above or below the hyoid, and moves with swallowing and tongue protrusion, unlike a thyroid swelling, which moves only with swallowing. A fistula is usually secondary to spontaneous discharge or drainage of an infected thyroglossal cyst. The treatment of both a cyst and a fistula is excision. In order to prevent recurrence, the remnant of the thyroglossal duct must be traced upwards and excised.

A horizontal incision is made over the cyst or an ellipse of skin is cut out to include a fistula opening. The platysma is divided in line with the skin incision, the deep cervical fascia is divided vertically in the midline and the strap muscles are separated. The cyst is mobilised and the upwards extension of the track is followed until it disappears deep to the body of the hyoid bone, to which it is densely adherent (Figure 23.10). The hyoid must then be separated from the underlying thyrohyoid membrane. There is a space between these structures, and the surgeon's fears of encountering the endotracheal tube in the operating field are normally groundless. The central 1 cm of the hyoid bone is cleared of muscle attachments and is then resected with bone nibblers so that it can be removed with



23.10 (a) The track from a thyroglossal cyst or sinus is intimately related to the hyoid bone and ends at the foramen caecum. (b) If the central portion of the hyoid is not excised with the adherent track on its deep surface, recurrence is likely. ⏎

the specimen. The dissection can then proceed into the tongue towards the foramen caecum. The track often disappears at this level, and entry into the oral cavity is unnecessary. The wound is closed with vacuum drainage.

Hemithyroidectomy

Hemithyroidectomy (thyroid lobectomy) is undertaken usually for diagnostic purposes, when preoperative investigations of an apparently solitary thyroid nodule have neither excluded nor confirmed malignancy. Imaging with ultrasound scanning identifies whether the nodule is solitary or, as is quite common, a dominant nodule in a multinodular goitre. It also differentiates solid from cystic nodules. Technetium uptake scanning will differentiate functioning ('hot') nodules from non-functioning ('cold') ones. Fine-needle aspiration cytology can diagnose colloid nodules, lymphoma and papillary, medullary and anaplastic cancer. It cannot, however, differentiate benign from malignant follicular tumours.

The most common indications for hemithyroidectomy include a solitary cold nodule with follicular cytology and a dominant cold nodule in a multinodular goitre with follicular cytology, as well as situations where the multinodular changes are confined to one lobe. A hemithyroidectomy is required for definitive histological diagnosis. A perioperative frozen section is advocated by some surgeons. However, most pathologists find that differentiating benign from malignant follicular tumours at frozen section is a particular problem, although the technique is useful in confirming a papillary carcinoma (which may be suspected but has not been proven on the basis of the preoperative cytology). The alternative is to await a definitive pathology report, with completion thyroidectomy, if indicated, undertaken as a separate later procedure.

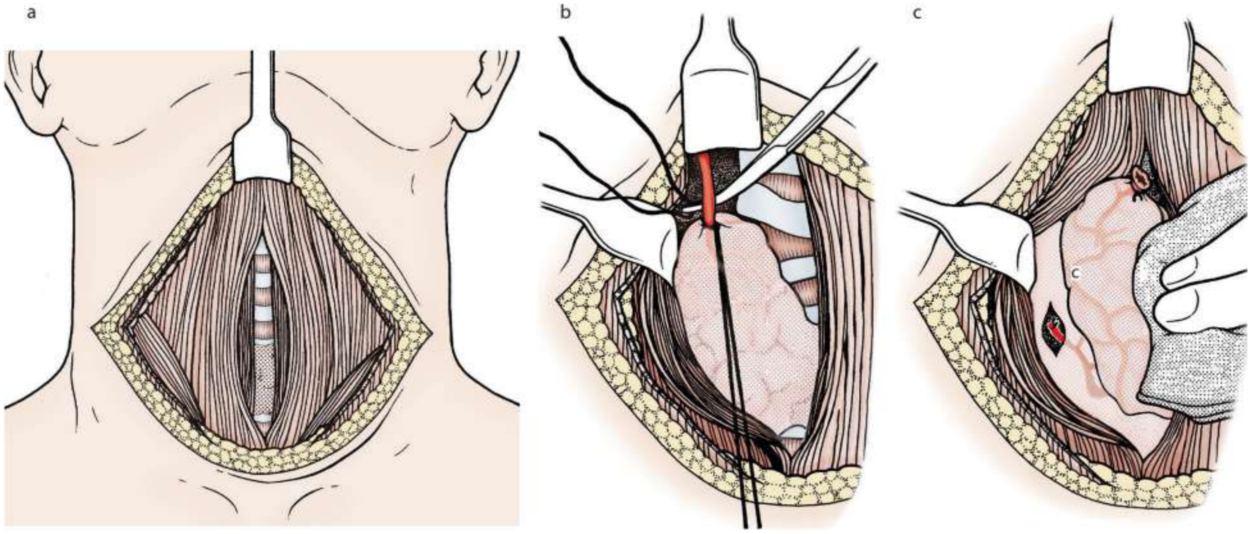
The 2015 American Thyroid Association guidelines suggest a thyroid lobectomy may have similar outcomes to a total thyroidectomy for certain low-risk, well-differentiated node-negative tumours.[9]

While medullary thyroid cancer is rare, it is generally managed in a more radical manner, and preoperative diagnosis, when possible, permits elective planned surgery. In particular, more extensive nodal surgery is undertaken, and this is easier if it is not complicated by previous thyroid surgery. When a preoperative diagnosis of differentiated thyroid cancer has been made, the possibility that this might be medullary cancer should be considered and this can be confirmed, or refuted, with either cytological immunostains for calcitonin or a serum calcitonin measurement.

The operation A slightly curved transverse skin crease incision is made 2–3 cm above the sternum (it should not be positioned lower than this or the central portion of the scar will hypertrophy). Platysma is incised in line with the skin and the skin and platysma flaps are elevated down to the sternum and up to the thyroid cartilage. Traditionally, 40–60 mL of 1 in 400,000 adrenaline was infiltrated into the superficial tissue of the flaps prior to the incision to reduce bleeding, but this is of less value when diathermy dissection is employed. A self-retaining Joll's retractor can be used to retract the flaps. The deep cervical fascia is incised vertically in the midline and the strap muscles are retracted laterally (Figure 23.11a). Horizontal division of the strap muscles for access is seldom necessary, even in large goitres, as the muscles in this situation have already been stretched by the enlarged gland. If division is necessary, the muscles should be divided high up, as their innervation is from below. They are repaired at the end of the procedure.

The assistant retracts the strap muscles laterally and away from the surface of the gland. Areolar tissue around the gland is divided and the middle and inferior thyroid veins are displayed. These require ligation and division. Skilled assistance is essential for this operation, as these veins are unsupported by surrounding tissue and are very delicate. The artery forceps on these veins must be released with minimal movement of the tip as the surgeon tightens the ligature. Alternatively, an aneurysm needle can be used to pass the ligature around the vein, which is then ligated in continuity before division. The deepest of the inferior thyroid veins may be in close proximity to the recurrent laryngeal nerve, and the final ligations in this area may have to wait until the nerve has been identified. Attention is next turned to the superior pole. With gentle traction on the now partially mobilised lobe, it should be possible to pass right-angled forceps behind the superior pole vessels and pass a mounted tie around them (Figure 23.11b). An aneurysm needle is also very useful for this step. The external laryngeal nerve is endangered during this manoeuvre, and it is important to try and find the window medial to the superior pole vessels and stay a few millimetres lateral to the surface of the larynx. The ligature is then tied as low as possible. A second ligature is tied above it, and artery forceps are placed immediately above this second ligature. The vessels are then divided between the ligatures and a further ligature is tied on the superior thyroid pedicle before the forceps are released. Too high a tie of these vessels also endangers the external laryngeal nerve. Many surgeons are now using the Harmonic® scalpel for division of all the thyroid vasculature.

The lobe is then rotated medially out of its bed. The assistant is now retracting in a deeper plane and the retractor is drawing the carotid sheath laterally. The medial retraction of the lobe by the assistant allows the recurrent laryngeal nerve to come into view. The inferior thyroid artery and the recurrent laryngeal nerve both lie beneath a thin fascial layer, which must be incised (Figure 23.11c). The inferior thyroid artery was traditionally then ligated in continuity, as lateral as possible to minimise any danger to the nerve. It is now recommended instead that close



23.11 A right thyroid lobectomy. (a) A horizontal skin and platysma incision is followed by elevation of the flaps. Vertical midline division of the cervical fascia and separation of the strap muscles exposes the gland. (b) The right strap muscles are retracted. Multiple small veins have been divided, and retraction has exposed the upper thyroid pole. The first ligature has been tied around the superior thyroid vessels close to the gland. (c) The retractor is now in a deeper plane and is retracting the carotid sheath laterally in addition to the strap muscles. The thyroid is retracted medially. An incision through the posterior fascia allows identification of the recurrent nerve, running in a vertical or oblique orientation. The inferior thyroid artery crosses the nerve. The artery runs transversely and can be seen to pulsate. The branches of the artery should be divided on the surface of the thyroid distal to the parathyroids. ⏎

dissection is continued after the nerve has been identified and the branches of the inferior thyroid artery are secured on the surface of the gland, in order to preserve parathyroid vasculature.

The final dissection of the deep portion of the gland off the recurrent nerve and the parathyroids is the most difficult, and must be performed with great precision. The nerve is closely related to the Berry's ligament, so careful dissection here is important to avoid injury to the nerve. The medial surface of the lobe then separates easily from the trachea and is finally only attached by the isthmus, which is divided close to the contralateral lobe. A haemostatic continuous absorbable suture in the isthmus will control haemorrhage or, alternatively, the isthmus can be divided with the Harmonic scalpel.

A deep vacuum drain is placed beneath the strap muscles before they are approximated. The platysma is sutured and finally the skin is closed using sutures or staples.

Total thyroidectomy

This is the standard operation for thyroid cancer. It is also increasingly employed for multinodular goitre and for the surgical management of thyrotoxicosis that has relapsed on medical treatment. It is also undertaken prophylactically in patients who are genetically at high risk of familial medullary thyroid cancer. The indication for excision of the whole thyroid in papillary and medullary cancer is the commonly multifocal pattern of the disease. In follicular cancer, the rationale is complete eradication of thyroid tissue so that any metastases can be identified and treated by uptake of radioactive iodine. If a definitive preoperative diagnosis is possible, as discussed in the section on hemithyroidectomy, a total thyroidectomy can be planned from the outset.

Operative procedure Surgery is essentially a bilateral hemithyroidectomy, but the risks involved are higher. Unilateral recurrent nerve damage leaves a patient with a deeper voice of reduced strength. Bilateral damage results in the paralysed cords migrating medially to obstruct the airway, and a tracheostomy is usually necessary. In addition, bilateral loss of parathyroid function, whether from excision or from ischaemic damage, may produce symptomatic hypocalcaemia. Thyroid replacement therapy will, of course, always be necessary.

Lymph node dissections with thyroidectomy

Surgical opinion is divided on the prognostic value of the diagnosis of nodal metastases in differentiated thyroid cancer. There is agreement, however, that if nodal dissection is necessary, a type III modified or functional dissection is undertaken. Opinion is also divided over the therapeutic value of prophylactic dissection of the clinically negative neck and whether it should be preceded by frozen section histology of the nodes. Preoperative imaging of cervical nodes, usually by ultrasound or CT scanning, can raise the suspicion of nodal metastases, and cytological confirmation by needle biopsy permits a more planned approach to surgery.

In *papillary thyroid cancer*, one view is that, in addition to a total thyroidectomy, the pre-tracheal and tracheo-oesophageal lymph nodes (level VI) are cleared, as this cervico-central group is the most commonly involved. Frozen section histology can then be obtained of a node in the middle portion of the ipsilateral deep cervical chain, as these level III nodes in the cervico-lateral region most frequently contain metastases. If this node is positive, a type III modified radical neck dissection is performed. However, many surgeons would elect for a total thyroidectomy without any lymph node dissection in the clinically negative neck, especially when preoperative imaging has also been negative.

In *follicular thyroid cancer*, lymph node metastases are less common than in papillary cancer, but distant metastases are more common. Although this changes the balance of risk, the issues that dictate the surgical strategy in the clinically negative neck are similar.

In *anaplastic thyroid cancer*, little is gained by radical surgery. Radiotherapy and chemotherapy may procure a short remission, and surgery is usually limited to excision of the isthmus to prevent airway obstruction.

In *medullary thyroid cancer*, the central and paratracheal lymph nodes (level VI) should be excised, and this dissection can be continued caudally to include upper mediastinal (level VII) nodes and the thymus gland. The deep lateral cervical nodes may also contain metastases. The advisability of a unilateral or bilateral modified neck dissection can again be determined on frozen section histology of a deep cervical node.

Subtotal thyroidectomy

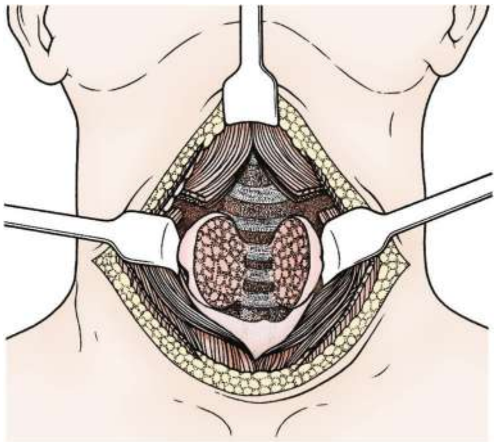
This was the standard operation both for a large goitre and for a toxic thyroid. In subtotal thyroidectomy, the remnant is left mainly to safeguard the parathyroid glands and their blood supply and to reduce the risk of injury to the recurrent laryngeal nerve. More recently, total, or near-total, thyroidectomy and thyroid replacement therapy have been advocated for both conditions, primarily to reduce the risk of recurrence of the goitre or of thyrotoxicosis.

In a large *multinodular goitre*, the aim may be purely cosmetic, but more commonly there are pressure effects on the trachea and, ultimately, on the oesophagus. *Hyperthyroidism* is primarily a medical condition. Surgery is indicated for patients who relapse after medical treatment and for those in whom the gland is nodular and enlarged in addition to being hyperactive. Thyrotoxicosis must be controlled by medical means prior to surgery. Antithyroid drugs are now commonly combined with beta-receptor blockade to prevent the cardiovascular manifestations of an increase in circulating thyroxine. Following total or near-total thyroidectomy, patients will become hypothyroid without thyroxine replacement therapy. After a classical subtotal thyroidectomy, hypothyroidism is related more to the nature of the disease and to the immunological changes triggered by the surgery than to whether the correct volume of thyroid remnant was retained. Traditionally, the surgical belief was that approximately one-eighth of the original gland should be retained.

Operative procedure Subtotal thyroidectomy proceeds in the same fashion as for a total thyroidectomy until after the inferior thyroid artery is (or its branches are) ligated. The lobes are then transected, leaving a cuff of posterior thyroid tissue, which lies on either side of the trachea from which the overlying isthmus has been removed (Figure 23.12). A continuous haemostatic suture may be inserted in each transected remnant, but with great care, as the residual thyroid tissue overlies the recurrent laryngeal nerve and the parathyroid glands.

Retrosternal goitres

The whole thyroid gland may be lying retrosternally or, more commonly, there is a retrosternal portion of a large goitre. The goitre is frequently symptomatic, and surgery is indicated for tracheal compression. The retrosternal goitre lies in the superior mediastinum above and anterior to the great vessels. It can usually be delivered up into the neck without difficulty. In situations where it cannot be delivered easily, the proximity to these vessels must be remembered and force avoided. In extremely rare cases, a median sternotomy is necessary for safe mobilisation of a retrosternal goitre (see Chapter 22).



23.12 Subtotal thyroidectomy. A small remnant of each lobe has been left bilaterally. The illustration shows a case in which partial division of the strap muscles proved necessary. ⏎

Parathyroidectomy

Parathyroidectomy is undertaken for hyperparathyroidism. *Primary hyperparathyroidism* is usually the result of a secreting adenoma in one gland. The remaining glands are small and hormonally suppressed. However, a spectrum of adenoma and hyperplasia can occur, particularly in some forms of multiple endocrine neoplasia (MEN) syndrome. In patients with renal pathology, the initial hormonal abnormality is a compensatory *secondary hyperparathyroidism*, with hyperplasia affecting all four glands. Finally, the overactive glands may become autonomous and *tertiary hyperparathyroidism* develops, which commonly involves more than one gland in hyperplastic or adenomatous change. When there is a solitary adenoma, only that gland should be excised, particularly when preoperative ultrasound and sestamibi (MIBI) scans correlate. When a hyperplastic process involves all of the glands, it has been commonly advocated that three glands, and half of the fourth gland, should be excised. More recently, removal of all four glands and maintenance replacement therapy with 1,25-dihydroxycholecalciferol has gained popularity, primarily to reduce the risk of recurrent hypercalcaemia. The operative strategy of surgeons operating on this condition will thus vary, depending on whether their referral practice is mainly of patients from a regional renal centre.

For the management of sporadic primary hyperparathyroidism, it is important to identify the side and position of what will be a solitary adenoma in 80% of cases. This avoids unnecessary bilateral exploration in the majority of patients. An ultrasound, CT or magnetic resonance imaging (MRI) scan may demonstrate an enlarged gland. MIBI scans initially proved invaluable before re-explorations, but they are now used routinely before most parathyroid surgery procedures. A combination of a positive MIBI scan and an anatomical scan showing concordance results in a 95% chance that the solitary adenoma will be found in the co-localised position. Prior to a re-exploration, these investigations can be repeated and, additionally, selective venous sampling can be helpful. Patients with hyperparathyroidism secondary to renal disease will require a bilateral neck exploration, as will those with a familial predisposition and those whose preoperative scans suggest multiglandular disease. However, the 80% of patients with suspected primary hyperparathyroidism only require a unilateral exploration on the side of the adenoma. Removal of one enlarged gland, with perioperative frozen section confirmation that it is parathyroid, and identification of one normal gland are sufficient.

Operative procedure Methylene blue is taken up selectively by the parathyroids, and the blue staining of the tissue is helpful in differentiating parathyroid tissue from lymph nodes or nodules of fat. It is administered in solution, as an infusion of 5 mg/kg over a 1-hour period. The colour differential diminishes after a further hour, and timing of the infusion can be difficult. Near-infrared fluorescence (NIRF)-based intraoperative visualisation and indocyanine green (ICG)-based techniques have also been used to aid detection.[10] Frozen section histology can be used for confirmation. The parathyroid adenoma may be immediately apparent after mobilisation of the thyroid, but sometimes parathyroid glands cannot be identified and may be lying in ectopic positions.[11,12] A *superior* gland that is not in its normal position is often lying more *dorsally* and adjacent to the oesophagus and may have migrated caudally as far as the posterior mediastinum. An *inferior* gland lies more *ventrally*, but it may have migrated caudally to lie in the anterior mediastinum or cranially to lie close to the submandibular gland. Parathyroid glands may also lie within the thyroid tissue. It must be remembered that 3% of individuals have only three glands and 13% have supernumerary glands.

Over the last decade there has been increasing interest in minimally invasive video-assisted thyroid and parathyroid surgery.[13] In some centres, parathyroid surgery is increasingly undertaken by this method.[14]

Revision surgery on the thyroid and parathyroid glands

Re-operation – whether for excision of the remnant of a thyroid lobe, excision of a recurrent goitre or repeat exploration for recurrent hyperparathyroidism – carries a greatly increased risk of damage to the recurrent laryngeal nerve. The anatomy may be both obscured and distorted by scar tissue, and the planes for safe dissection are obliterated. Avoidance of these problems is one of the reasons why total thyroidectomy is gaining in popularity. Surgery for a recurrent goitre may be requested for cosmetic reasons and should not be undertaken lightly. When reoperation is necessary, the surgeon must take extra care during dissection and the patient must be warned preoperatively of the increased risk of nerve damage. Referral to a surgeon with special expertise should always be considered in this situation.

Postoperative complications of thyroid and parathyroid surgery

Airway complications Postoperative stridor can occur for several reasons:

- *Bilateral recurrent nerve damage.* An immediate problem with maintenance of the airway on extubation will occur if there has been bilateral nerve damage. Laryngoscopy confirms paralysed, adducted cords obstructing the airway. Reintubation will have to be followed by a tracheostomy, which will usually be permanent unless the damage is no more than a temporary neurapraxia.
- *Tracheomalacia* is a complication of very large goitres and is therefore seldom encountered in surgical practice in the developed world. Airway obstruction from postoperative tracheal collapse may necessitate an emergency tracheostomy. When tracheomalacia is recognised intraoperatively, an elective temporary tracheostomy should therefore be considered.
- *Haemorrhage* deep to the strap muscles compresses, and finally occludes, the airway. Treatment consists of opening the wound to drain the haematoma and relieve the pressure. There is frequently some warning of this impending disaster, and the patient can then be returned to the operating theatre for urgent intervention. When warning signs have been ignored, an acute emergency may present, for which restoration of the airway in an unconscious anoxic patient must be achieved immediately. Sutures in the skin, platysma and strap muscles are cut at the bedside, the clot is evacuated and the patient is then returned to theatre for re-suturing of the wound. Clip removers should always be readily available at the patient's bedside for this emergency if clips have been used for skin closure.

Biochemical complications Early and late disturbances in thyroid and parathyroid endocrine balance are common:

- A *thyroid crisis* can occur postoperatively in a patient whose thyrotoxicosis was inadequately controlled preoperatively. Management is medical control, with sedation and beta blockade. Preoperative control of thyrotoxicosis is therefore very important.
- *Hypothyroidism* is inevitable after a total thyroidectomy and is a common late complication of a subtotal thyroidectomy. It also occurs in over 10% of patients following a hemithyroidectomy. Hypothyroidism does not, however, pose problems in the immediate postoperative period, and thyroxine replacement therapy should be delayed initially if thyroidectomy is undertaken for differentiated

thyroid cancer, as postoperative radioactive iodine scanning is facilitated by thyroid-stimulating hormone stimulation.

- *Hypocalcaemia* is the manifestation of insufficient parathyroid hormone secretion. Parathyroid glands may have been excised or rendered ischaemic by surgery. Presentation with tetany should be avoidable, as postoperative assessment of serum calcium is mandatory. This allows calcium and, if necessary, 1,25-dihydroxycholecalciferol support to be given should hypocalcaemia develop. Spontaneous recovery of parathyroid function is common.

THE SALIVARY GLANDS

Surgery of the parotid and submandibular glands requires a detailed understanding of the anatomy.

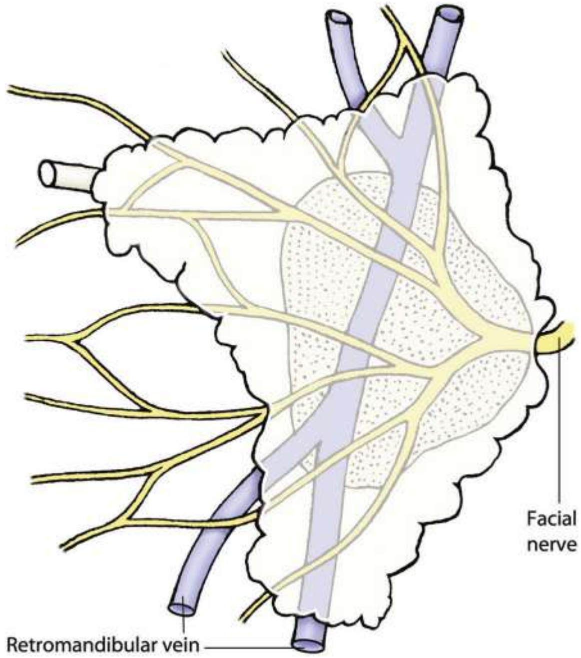
THE PAROTID GLAND

Any surgery on the parotid gland risks injury to the facial nerve. Surgeons who operate infrequently in this area are more likely to injure the nerve and, for this reason, a parotidectomy is now seldom undertaken by a generalist, who instead will refer a patient to a head and neck specialist.

Surgical anatomy

The parotid gland lies in the space behind the mandible, below the external ear, in front of the mastoid process, and extends forwards on the lateral surface of the masseter. The gland overlies the posterior belly of the digastric below and deeply it is adherent to the styloid process and its muscles. It is enclosed in a sheath, which is derived from the deep cervical fascia and sends processes into the gland to divide it into lobules. The *upper pole* of the gland lies just below the zygomatic arch and is wedged between the meatus and the mandibular joint. The superficial temporal vessels, the temporal branches of the facial nerve and the auriculotemporal nerve are found entering, or leaving, the gland near the upper pole. The marginal mandibular and cervical branches of the facial nerve and the two divisions of the retromandibular vein emerge from the *lower pole*. From the *anterior border* emerge the zygomatic and buccal branches of the facial nerve and, on a deeper plane, the parotid duct.

The *external carotid artery* ascends through the deep part of the gland. It terminates behind the neck of the mandible by dividing into maxillary and superficial temporal arteries. The *facial nerve*, after emerging from the stylomastoid foramen, almost immediately enters the posteromedial surface of the gland and, after about 2 cm, splits into two main subdivisions, from which the terminal branches arise. The *retromandibular vein* forms within the substance of the gland by the union of the superficial temporal and maxillary veins and emerges from the lower pole usually as two trunks. The anatomy is remarkably consistent, with the nerve and its branches lying just superficial to the veins (Figure 23.13). The *faciovenous plane*, in which the veins and the branches of the facial nerve lie, arbitrarily divides the gland into a superficial and a deep part. It was the appreciation of this anatomy that allowed surgery on the parotid with preservation of the facial nerve.[15]



23.13 The faciovenous plane as described by Patey and Ranger. The retromandibular vein traverses the gland in a vertical direction, while the facial nerve trunk enters posteriorly and its branches fan out to leave the gland superiorly, anteriorly and inferiorly. ⏎

Removal of a parotid duct calculus

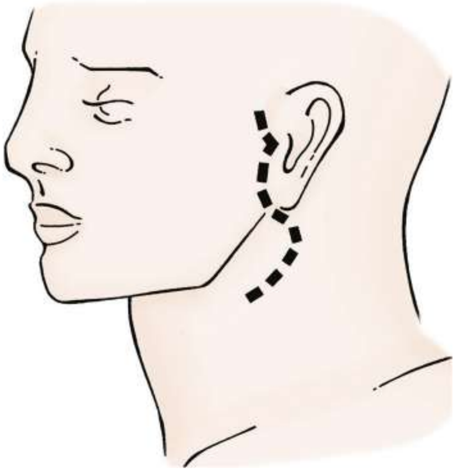
A calculus impacted in the duct and obstructing the gland is easily palpable from within the mouth. A temporary suture is placed around the duct, proximal and distal to the stone to prevent displacement, and a small incision is made directly over the stone to deliver it into the mouth. When the stone is lodged in the proximal section of the parotid duct, the buccal branch of the facial nerve is vulnerable to damage, as it is closely associated with the proximal segment of the duct. After removal of the stone, no suturing is required to close the opening in the duct. When expertise is available, sialendoscopy and stone retrieval can be used for smaller stones up to 4 mm in size. Laser and pneumatic lithotripsy can be used to fragment medium-sized stones, and a combined endoscopy-assisted surgical approach is needed for larger stones of 8 mm or larger.[16,17]

Superficial parotidectomy

Superficial parotidectomy is most commonly undertaken for a lump within the gland. Fine needle aspiration and MRI can confirm the diagnosis preoperatively, but prior to the excision the malignant potential of the lump is not always known. Adenolymphomas are benign. Pleomorphic adenomas are locally recurrent if excision has been incomplete. One of the rarer salivary gland carcinomas may be suspected preoperatively if growth is rapid or if there is any loss of facial nerve function. However, the majority of malignant parotid tumours do not present with abnormalities of facial nerve function. Pain is also an ominous feature, but can occur in benign disease from haemorrhage into a cystic space.

A nerve monitor, if available, is placed before the initial incision is made, as this will warn the surgeon when the dissection is approaching the facial nerve. The anaesthetist must keep the patient non-paralysed for the device to be effective. The incision should give good access, with well-vascularised flaps and a scar that will lie inconspicuously in skin creases. A suitable cervico-facial incision is shown in Figure 23.14. It is deepened through the platysma until the surface of the parotid fascia is reached, and the anterior skin and platysma flap is elevated to expose the parotid gland with its covering fascia. Care must be taken to avoid injury to the branches of the facial nerve emerging from the anterior border of the gland.

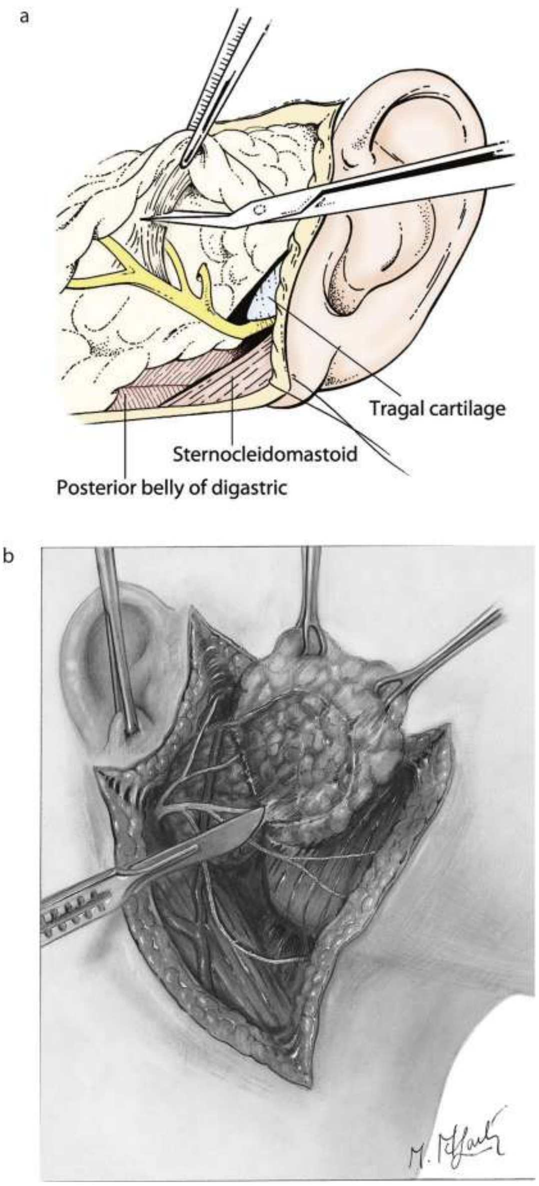
The dissection in a superficial parotidectomy is based on identification of the facial nerve before it enters the gland and, by following the nerve and its branches, removing all tissue superficial to this faciovenous plane. The inferior pole of the parotid is lifted off the surface of the sternocleidomastoid muscle. The greater auricular nerve is found crossing the lateral surface of the sternocleidomastoid and is divided close to the gland. The sternocleidomastoid is then retracted posteriorly and the posterior belly of the digastric is identified. This is followed up to the mastoid process. The facial nerve is usually at the same depth as the posterior belly of the digastric muscle, and the surgeon should be cautious about dissecting at a level deeper than this. The dissection is then carried deeply, along the perichondrium of the tragal cartilage, and parotid tissue is separated from the cartilage. The cartilage ends in a ‘pointer’, which points to the facial nerve, usually 1 cm medially and inferiorly (Figure 23.15a). A bridge of parotid tissue, overlying the facial nerve, lies between this pointer and the digastric muscle. This can now be elevated to expose the nerve, which is very deep at this point. Another palpable bony landmark is the tympanomastoid suture line, and the nerve exits the stylomastoid foramen just anterior to this.



23.14 A cervico-facial incision for parotid surgery. ⏎

Once the nerve has been identified, it is followed forwards into the gland. It runs rapidly towards the surface, and account has to be taken of this obliquity during dissection. After about 2 cm, it divides into upper and lower divisions. Fine artery forceps are inserted along the superficial surface of the nerve and the glandular tissue is lifted forwards to display fine strands of tissue between the nerve and gland, which are cut with scissors. The branches of the upper division are followed until they emerge from the gland. Between each branch of the nerve there will be a bridge of parotid tissue passing between the superficial and deep portions of the gland, which must be divided. No major vessels should be encountered, but ligation of small vessels will be required, especially as diathermy dissection is dangerous in the proximity of the nerve. However, bipolar diathermy to individual small vessels is generally safe. A similar dissection is then performed along the lower division of the facial nerve and its subdivisions. The superficial part of the gland can now be removed, leaving the deep portion of the gland and the parotid duct *in situ*. The whole of the superficial part of the gland does not need to be removed for a lower pole tumour, for which a partial superficial parotidectomy is commonly performed.

As tumours are commonly in the superficial part of the gland, they can be removed by a superficial parotidectomy. However, the deep aspect of a tumour may be exposed by this dissection and great care must be taken to avoid breaching the tumour. Occasionally, a tumour extends deep to the faciovenous plane in the tissue bridge between the branches of the nerve. It is usually possible to retract the nerves with slings and excise the tumour intact without sacrificing nerves. A malignant tumour may invade nerve, and one or more of the branches may have to be sacrificed.



23.15 Superficial left parotidectomy. (a) The facial nerve is identified by deep dissection on the surface of the tragal cartilage. The superficial parotid tissue is lifted forwards and the tissue bridges, which pass between branches of the facial nerve to the deep portion of the gland, are divided. (b) The facial nerve and its branches exposed at the end of a right superficial parotidectomy (an original drawing from the 1954 edition by Margaret McLarty, a founder member of the Medical Artists' Association of Great Britain). ⏎

At the end of the dissection, the facial nerve and its branches lie exposed on the surface of the residual gland (Figure 23.15b). From the upper division, there should be a temporal branch to the forehead; zygomatic branches, frequently two branches, that cross the zygoma to the corner of the eye; and a large buccal branch that runs parallel to the duct and supplies the lower eyelid, nose and upper lip. An additional smaller buccal branch is often seen below the duct. From the lower division, there should be branches to the corner of the mouth and lower lip and to the platysma. If all these branches have been identified and are anatomically intact, the surgeon can be relatively reassured that any immediate postoperative paralysis is no more than a neuropraxia and will recover, often within 48 hours, but may persist longer. A severed nerve can be sutured or, if a portion has been excised, a nerve graft is a possibility, using the greater auricular or sural nerve (see also Chapter 21). The wound is closed over a suction drain with separate closure of the platysma and the skin.

In a superficial parotidectomy, the dissection is not infrequently on the deep aspect of the tumour if it is lying on, or extending between, branches of the facial nerve. This has led some surgeons to explore whether a precise local excision as an extracapsular dissection, in contrast with the old-fashioned crude enucleations, is not in fact oncologically inferior to a superficial parotidectomy.[18]

Extracapsular dissection

This approach is appropriate for single, proven benign lesions in the superficial lobe. The lesion is marked preoperatively and a preauricular incision is deepened to raise a skin flap just over the parotid fascia to expose the tumour. The margins are now again marked with a sterile marker. The overlying fascia is then incised in a cruciate manner with each arm of the cross extended at least 1 cm beyond the marked margin. Four haemostats are used to lift the parotid fascia upwards and outwards. This traction is crucial in allowing the tissue planes to open up. A very meticulous blunt dissection is carried out at least 3 mm away from the tumour, being cautious not to breach the capsule or spill tumour. The use of intraoperative nerve monitoring and magnification with surgical loupes aids identification of facial nerve branches that may be encountered during dissection. Any tissue is divided only when the blades of the dissecting scissors can be seen through it, to ensure inadvertent nerve injury is avoided. The tumour is removed with a margin of normal parotid tissue around it and the wound is then closed in layers over a suction drain. The results from extracapsular dissection for benign tumours have been promising, with a lower incidence of nerve injury and Frey's syndrome postoperatively.[18–20]

Total parotidectomy

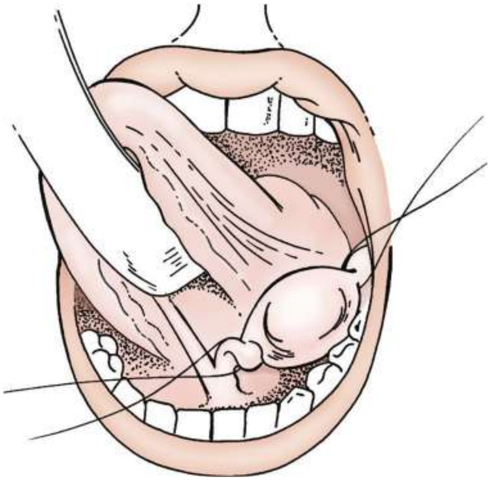
A total parotidectomy with sacrifice of the facial nerve may be unavoidable in the excision of a malignant parotid tumour that has extensively invaded the nerve. A facial nerve paralysis is inevitable, but a facial nerve graft (with the greater auricular nerve used to bridge the defect and sutured using the operating microscope) offers the potential for some functional recovery once regrowth of axons has occurred. In most instances, it is possible to save some of the facial nerve branches and sacrifice only those that are directly invaded, especially as no survival benefit has been shown for a pre-emptive radical parotidectomy with the sacrifice of uninvolved branches of the facial nerve. Sometimes, a total parotidectomy is combined with excision of the temporomandibular joint, the mastoid process, the external meatus and the overlying soft tissue for a locally aggressive malignant tumour. Unfortunately, such radical surgery is disfiguring and seldom curative.

A total parotidectomy, with preservation of the facial nerve, sometimes referred to as a total conservative parotidectomy, is an appropriate operation for a tumour lying wholly, or partially, in the deep portion of the gland. The initial dissection is similar to that for a partial parotidectomy. The plane is developed between the superficial and deep portions of the gland, except in the vicinity of the tumour. Then, depending on the position of the tumour, retraction of either the superior or the inferior division of the nerve off the underlying tumour allows access to dissect around the deep portion of the gland. Ligation of the retromandibular vein is necessary, but the external carotid artery can usually be separated from the deep part of the gland unless there is direct tumour invasion. Ligation of the external carotid artery has no sequelae.

THE SUBMANDIBULAR GLAND

Surgical anatomy

The submandibular gland is situated partly below the mandible and partly deep to it. The body of the gland overlaps both bellies of digastric inferiorly. It is enclosed in a loose sheath of deep cervical fascia. The *inferolateral surface* is covered only by platysma and cervical fascia. The *medial surface* lies on (in order from anterior to posterior) the mylohyoid, the hyoglossus and the pharyngeal wall. Between the gland and the hyoglossus are the lingual nerve, the submandibular ganglion and the hypoglossal nerve. The *deep part of the gland* is a prolongation extending from its medial surface and lying under cover of the mylohyoid. It lies alongside the *submandibular duct*, which also arises from the medial surface of the gland. The duct opens into the mouth on the sublingual papilla at the side of the frenulum of the tongue. The *facial artery* ascends in a deep groove medial to the posterior end of the gland and then turns downwards and laterally between the gland and the mandible to enter the face at the anterior border of the masseter. The anterior facial vein descends on the inferolateral surface of the gland.



23.16 Removal of a left submandibular duct calculus. The tongue is held to the opposite side and a suture is placed around the duct, proximal and distal to the calculus, to prevent displacement. An incision is made directly over the calculus. ⏎

Removal of a submandibular duct calculus

A calculus in the duct is palpable intraorally and can be removed very simply under local anaesthesia. Two temporary stay sutures should, however, be placed around the duct on either side of the calculus and retracted upwards. This prevents displacement of the calculus back into the gland (Figure 23.16). The thickened duct is then incised longitudinally over the calculus, which extrudes into the mouth. There is no need to suture the incision. If the stone is very far back in the duct, then it is usually safer to remove the gland, as attempts at per-oral removal of a posterior calculus risk damage to the lingual nerve. Similar to parotid gland calculi, sialendoscopic techniques may also be used when available.

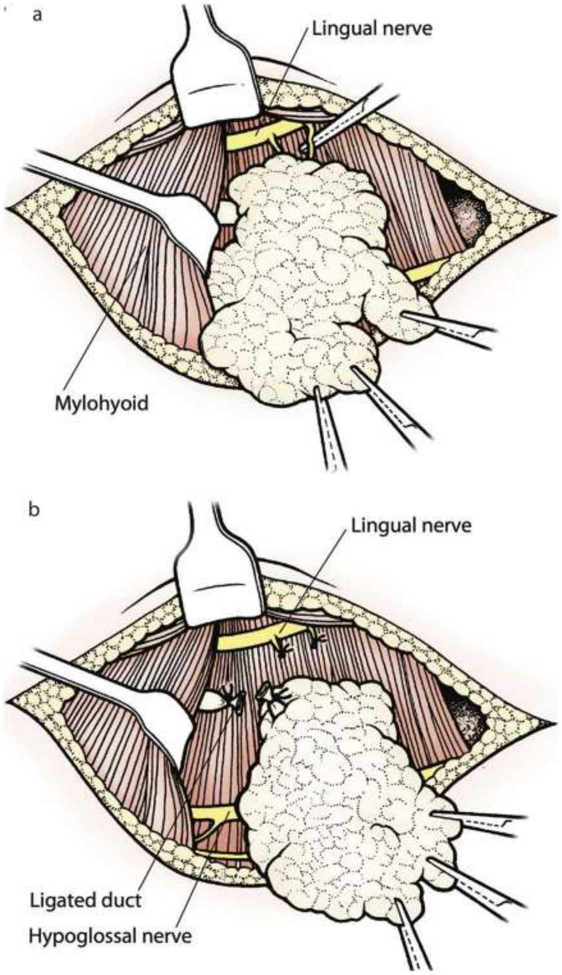
Submandibular gland excision

Submandibular gland excision is advised when the gland is chronically inflamed or is the site of repeated stone formation. It is also a suitable operation for a pleomorphic adenoma. Tumours arising within the submandibular gland are less common than in the parotid, but are more likely to be malignant. Excision for a malignant submandibular salivary tumour may need to be combined with a neck dissection.

Secondary carcinoma of the submandibular lymph nodes is commonly encountered, and may initially be mistaken for a primary salivary gland tumour. Many of these nodes are inseparable from the gland and, if excision is planned, the gland must be removed *en bloc* with the nodes. However, the correct management of metastatic malignant submandibular glands is that of the underlying pathology. The primary malignancy must be sought and an *en bloc* excision planned if the tumour is still operable.

A submandibular gland excision commences with a horizontal skin crease incision, two finger breadths below the ramus of the mandible, and the incision is deepened down to the body of the gland. A superior flap, consisting of skin, platysma and the investing fascia of the gland, is then raised up to the ramus of the mandible and retracted to expose the whole superficial surface of the gland. The aim is to avoid damaging the marginal mandibular branch of the facial nerve, which lies between the platysma and the fascia usually 2 cm below the mandible. It is easily injured if a more superficial upper flap is raised. In a submandibular gland excision for a pleomorphic adenoma, an extracapsular dissection, rather than the subcapsular dissection described above, is recommended.

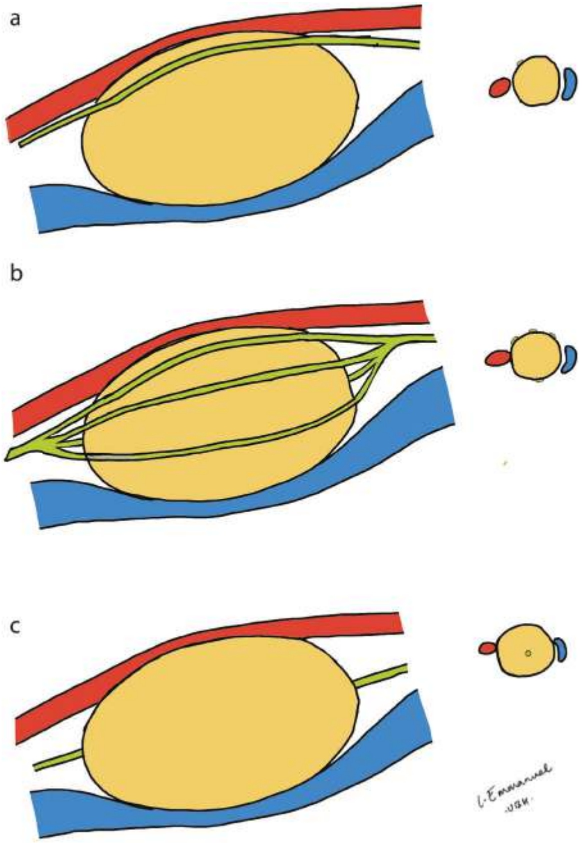
The facial vein, crossing superficial to the gland, is ligated and divided. Although the facial artery can be dissected out of its groove on the deep surface of the gland, it is simpler to divide and ligate it above and below. It is divided first at the upper border of the gland as it emerges from behind the posterior pole. The gland can now be dissected off the ramus of the mandible and the submental vessels secured. The anterior part of the gland is then dissected backwards off the surfaces of the anterior belly of the digastric and the mylohyoid muscles. The posterior border of the mylohyoid is identified and retracted anteriorly to display the deep part of the gland and its duct. Inferoposterior retraction of the partially mobilised gland will pull the lingual nerve down in a U-shape, where it is attached to the gland by the submandibular ganglion (Figure 23.17a). This attachment, and the accompanying small vessels, require ligation and division. The hypoglossal nerve may be visible inferiorly (Figure 23.17b), but it is often lying in a slightly deeper plane, protected from the operating field. An absorbable suture is used for ligation of the duct, which is divided as far anteriorly as possible to ensure removal of any small calculi dislodged into the duct. A small bridge of salivary gland tissue may have to be transected at this point if the sublingual gland is continuous with the submandibular gland. The only attachment now is the facial artery, which is ligated and divided for the second time at the lower border of the posterior pole. A short segment of artery is thus removed with the gland and, although this is not always necessary, it makes the dissection easier. A small suction drain to the bed of the gland is brought out posteriorly and the wound is closed with sutures to the platysma followed by skin closure.



23.17 Excision of a left submandibular gland. (a) The facial artery has been divided above the gland and the superficial portion of the gland has been dissected off the mylohyoid, which is now retracted forwards. The tented lingual nerve is visible. (b) The attachments to the lingual nerve have been divided and the submandibular duct is ligated. The hypoglossal nerve is visible inferiorly. ⏎

PERIPHERAL NERVE TUMOURS OF THE NECK

Extracranial peripheral nerve sheath tumours of the neck are mostly benign schwannomas or neurofibromas. The patient may have symptoms based on the nerve of origin or due to local pressure effects. Most of these tumours are benign and slow growing, with low malignant potential. It is therefore prudent to balance the morbidity of significant neurological deficits from complete *en bloc* excision with adopting



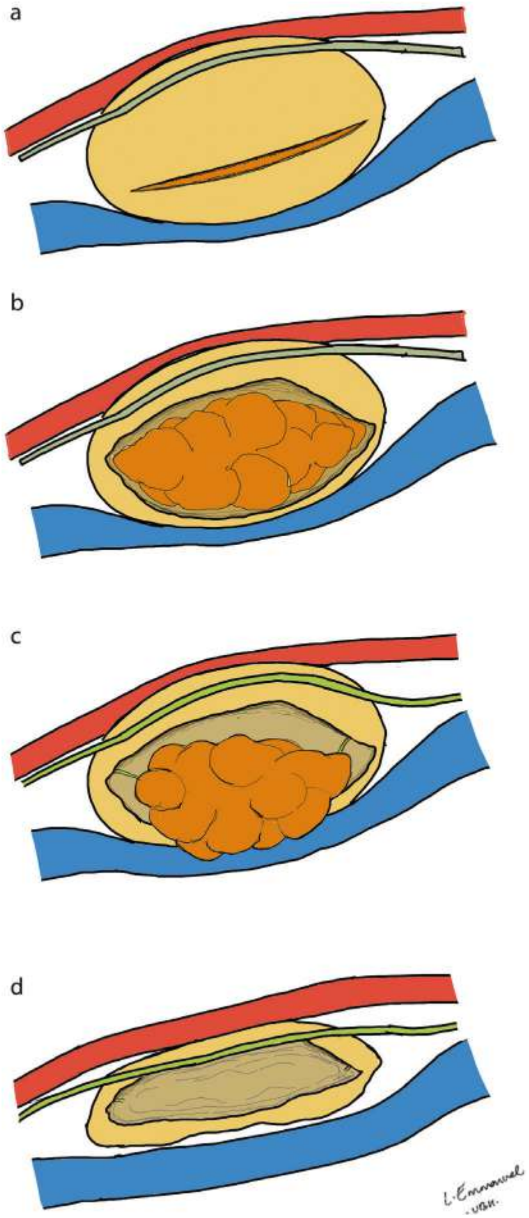
23.18 A vagal schwannoma lying between the common carotid and the internal jugular vein, pushing them apart. The nerve may be stretched eccentrically (a) or the bundles may be splayed by the tumour (b). (c) A neurofibroma of the vagus nerve, with the tumour growing around the nerve. ⏎

a nerve-sparing conservative excision.[21,22] Most arise from the vagus or the sympathetic chain, while the rest may be from cranial nerves IX, XI and XII, cervical sensory nerves, or the brachial plexus.

Schwannomas can be managed with intracapsular enucleation and preservation of the nerve. The tumour grows eccentrically with the nerve bundle visible on the outer aspect of the capsule or may splay the bundles apart on the periphery (Figure 23.18a,b). On the other hand, neurofibromas are intimately associated with the nerve fibres making nerve preservation difficult (Figure 23.18c).

OPERATIVE PROCEDURE

The patient is positioned with a shoulder roll and a head ring to allow adequate neck extension. A longitudinal incision along the anteromedial aspect of the sternocleidomastoid allows good exposure with visualisation of the proximal and distal uninvolved nerve segments. In addition, this facilitates proximal and distal vascular control if needed. Alternatively, for smaller lesions, a transverse incision over the swelling can also be utilised. Subplatysmal flaps are raised and retracted away. The lesion is then identified and, often, the nerve of origin can be recognised. The use of intraoperative nerve monitoring, and magnification, aids in identifying the nerve bundles, which are splayed across the lesion. Most schwannomas can be removed with preservation of the nerve. The capsule is entered at a point farthest from the nerve bundle and the contents enucleated, leaving the capsule and the nerve bundles intact (Figure 23.19a). The tumour



23.19 Intracapsular enucleation of a vagal schwannoma. (a) Incision over the capsule farthest from the nerve. (b, c) Intracapsular enucleation, preserving the capsule and nerve; only the involved fascicle is divided. (d) After excision, with the nerve preserved over the capsule. ⏎

is carefully dissected out, preserving the capsule and nerve bundles over it. Often, it is possible to identify a single nerve branch from which the tumour arises. This may need to be divided, while preserving the rest of the nerve (Figure 23.19c). Nerve preservation may not always be possible in neurofibromas; however, a conservative excision or debulking can be considered with the aim of nerve function preservation.[21] It is imperative that any thermal energy device, or electrocautery, is avoided to prevent damage to the nerve.

SURGERY OF THE LARYNX, PHARYNX AND TRACHEA

Only the general surgeon who is unable to refer patients to a specialist will need to operate on these structures, all of which lie within the area of expertise of an ENT or head and neck surgeon.

TRACHEOSTOMY

This was once a common operation for life-threatening obstruction of the upper airway. The situation is now usually more satisfactorily managed by emergency endotracheal intubation, and it is only in exceptional circumstances that intubation is not possible. Endotracheal intubation is the standard method for control of a patient's airway and is used both for the patient who is deeply unconscious with no gag reflex to protect the lower airway and for the patient requiring ventilatory support. However, long-term intubation of the larynx is damaging, and a decision regarding the need to convert to a tracheostomy should usually be made if the patient cannot be extubated within 2 weeks. This conversion to a tracheostomy is now commonly performed percutaneously in the intensive care unit by anaesthetists using specially designed kits. Most other tracheostomies are fashioned by ENT or head and neck surgeons at the completion of a major resection. It is therefore now rare for a general surgeon working in a hospital with ENT surgeons and a well-developed anaesthetic service to undertake a tracheostomy either electively or in an emergency.

ANAESTHESIA

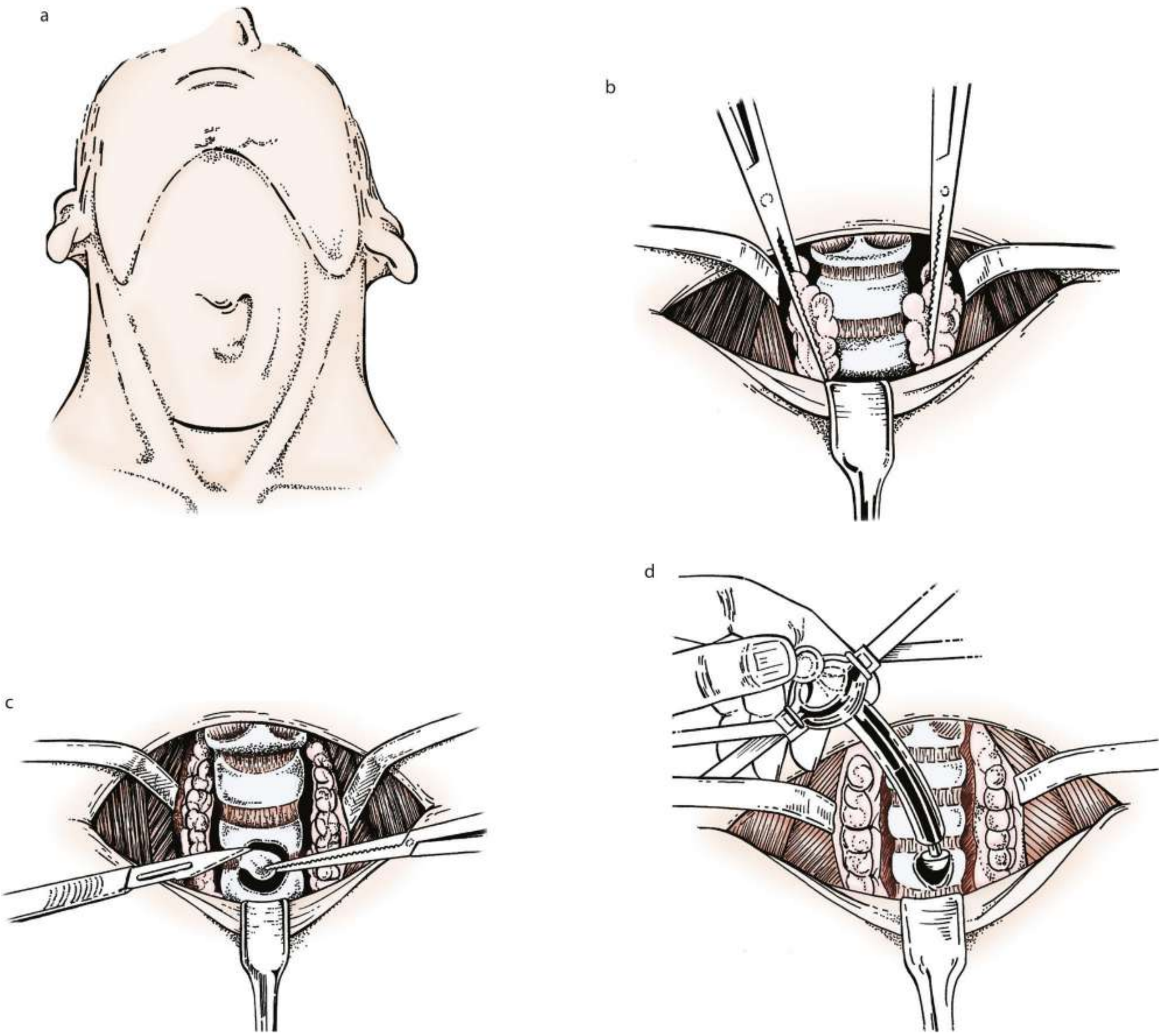
Ideal operative conditions include a general anaesthetic with the airway secured with an endotracheal tube. However, when a general surgeon has to perform a tracheostomy, it will almost always be in an emergency, in suboptimal conditions, and on an un-anaesthetised patient with no airway protection. In the unconscious, deeply cyanosed patient, no anaesthesia is needed and no further delay is justified. In the conscious, distressed patient with partial airway obstruction, lidocaine with adrenaline is infiltrated deep to the proposed skin incision. In the developing world, the most common scenario is a distressed baby or toddler with increasing airway obstruction from diphtheria and no skilled anaesthetic personnel or facilities available. Secure restraint of the child is mandatory. The child is wrapped in a sheet so that the arms are held firmly, and one assistant holds the child's body. A second assistant holds the child's head, comforts the child, maintains oxygen delivery and aspirates secretions from the upper airway.

OPERATIVE PROCEDURE

A transverse incision midway between the cricoid cartilage and the suprasternal notch is deepened through platysma (Figure 23.20a). In an emergency, a vertical incision is acceptable. The strap muscles are separated in the midline and the trachea is palpated, with the overlying thyroid isthmus, under the cervical fascia. The thyroid isthmus is freed from the trachea and divided between clamps and the ends oversewn with an absorbable suture (Figure 23.20b). Inferior thyroid veins may cross the operative field and require ligation and division. The cricoid and upper tracheal rings are now easily identified.

A surgeon with limited experience in tracheostomy formation will tend to drift cranially, as, in the adult, the trachea becomes progressively deeper as it is traced distally and, in the child, the innominate vein and the thymus may lie anterior to the trachea above the suprasternal notch. In addition, the apical pleura and the obstructed lungs will bulge up into the wound. It is important, however, that the tracheostomy is made at the level of the second to fourth tracheal ring, as a more proximal tracheostomy damages the cricoid cartilage and a subglottic stenosis may follow. The damage may be direct mechanical damage from a tracheostomy performed through the cricoid cartilage itself, but the cricoid can also be damaged by a perichondritis from an adjacent tracheostomy placed through the first tracheal ring.

A vertical midline incision in the trachea will allow insertion of the tube in a child or young adult. This is the technique least likely to cause a tracheal stenosis or a failure of closure of a temporary tracheostomy. However, in an older patient with calcification of the trachea, it is usually more satisfactory to remove a small disc of the second or, preferably, the third ring (Figure 23.20c). At this point, the anaesthetist is advised to withdraw the endotracheal tube (if the procedure is being performed under general anaesthesia). Blood is aspirated from the trachea, the tracheostomy tube is inserted and the wound is closed (Figure 23.20d). This should be only a loose closure,



23.20 Tracheostomy. (a) A horizontal incision leaves a less conspicuous scar. (b) The thyroid isthmus is divided to expose the trachea. (c) A disc of a calcified tracheal ring can be excised. (d) The tracheostomy tube is inserted. ⏎

or surgical emphysema may be troublesome. This initial tube should be sewn and taped in place because, if it becomes displaced, replacement in the first 72 hours before a track has been established is difficult.

PERCUTANEOUS TRACHEOSTOMY

Percutaneous tracheostomy is performed through an initial small skin incision. A needle with cannula is introduced into the trachea, the needle is removed and a guide wire is inserted through the cannula, which is in turn withdrawn. After the track has been dilated by forceps or by serial plastic dilators passed over the guide wire, the tracheostomy tube is inserted.

BRANCHIAL CYSTS AND FISTULAE

These are congenital abnormalities associated with the failure of obliteration of branchial clefts. A branchial cyst presents most often in late childhood or early adult life as a deep cystic swelling at the anterior border of the sternocleidomastoid, between its upper third and lower two-thirds. A branchial fistula is apparent at birth as an external opening near the anterior border of the sternocleidomastoid, close to its distal insertion. The internal opening is usually in the tonsillar fossa.

A skin crease incision over a branchial cyst affords adequate access for its excision (Figure 23.21a). The incision through the skin and platysma should be at least 2 cm below the angle of the jaw in order to avoid the marginal mandibular branch of the facial nerve. The deep cervical fascia is incised along the anterior border of the sternocleidomastoid. The cyst can then be carefully enucleated, but a search should be made for a deep extension. If present, this track will pass between the internal and external carotid arteries to the pharynx in the region of the tonsillar fossa and must be excised (Figure 23.21c).

A branchial fistula will frequently require two incisions, as the first elliptical incision to excise the external opening will be too low for higher access (Figure 23.21b). The track is often incomplete and ends blindly, but again the surgeon must be prepared to follow the track between the carotids if necessary. Branchial cyst and fistula surgery should not, therefore, be approached lightly by a surgeon who is infrequently performing neck surgery.

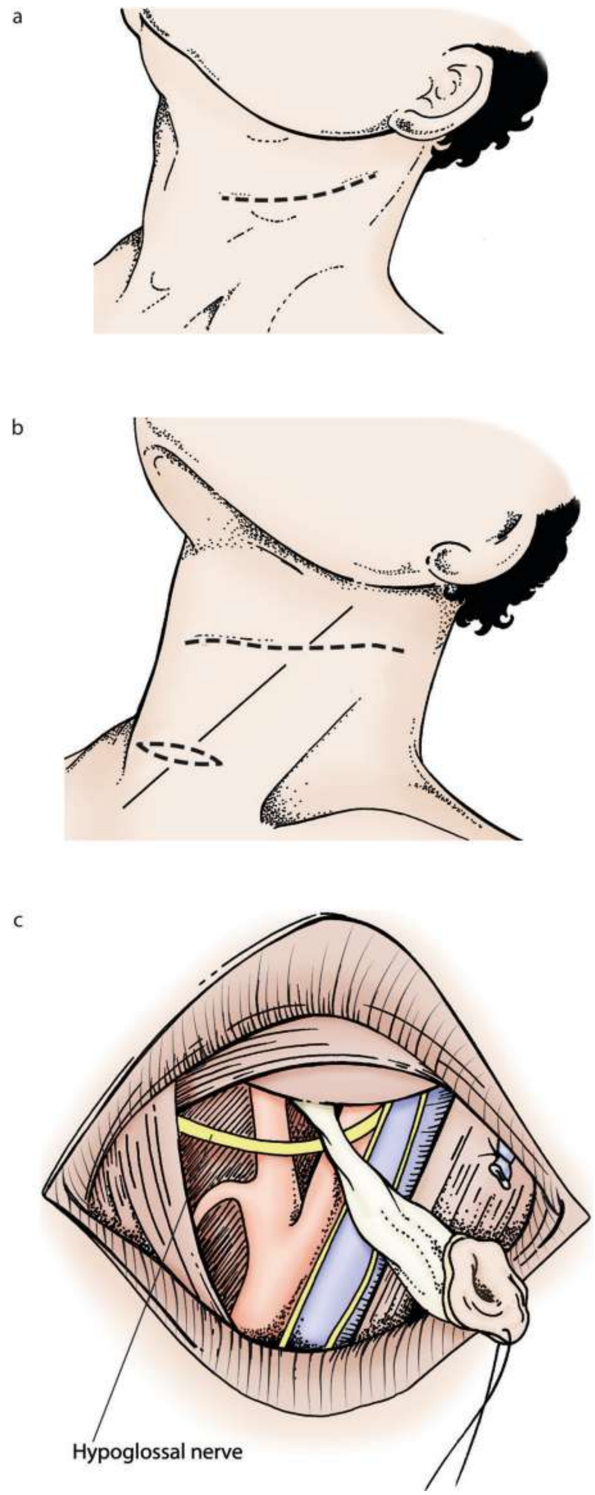
Pharyngeal pouch

The common form of the pharyngeal pouch is an acquired posterior diverticulum between the thyro- and cricopharyngeus in which food becomes trapped. Failure of relaxation of the cricopharyngeus is thought to be the underlying pathology. The fundus of the pouch lies alongside the oesophagus, which is then compressed by the pouch (Figure 23.22).

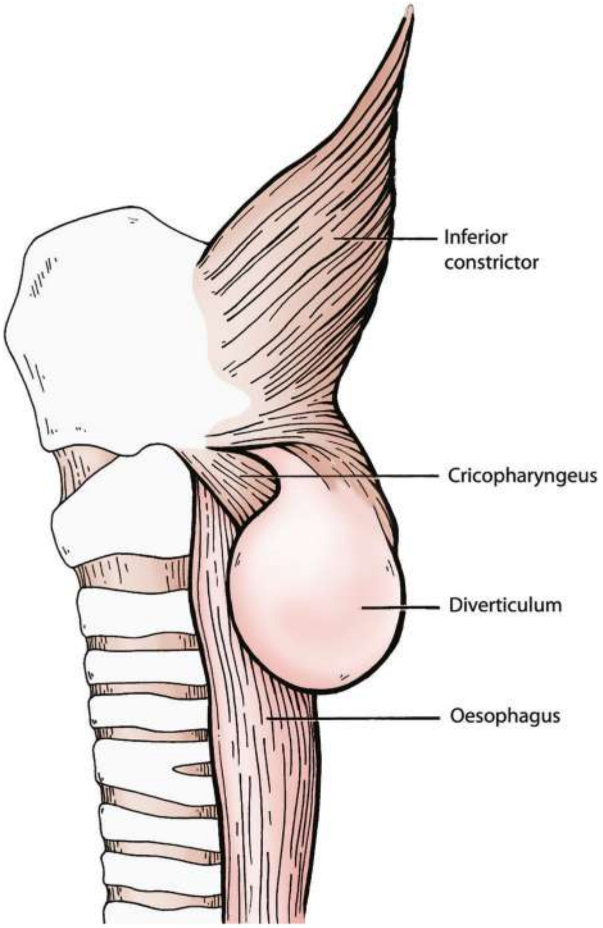
Endoscopic stapling procedures are increasingly popular in expert hands but, if an open technique is required, the pouch is packed with gauze at a preliminary endoscopy to facilitate its identification. A standard cervical approach to the oesophagus (see the section 'Surgery of the oesophagus') brings the dissection onto the gauze-filled pouch lying behind the oesophagus, from which it must be separated. The plane around the fundus of the pouch is then followed up to its neck and the neck of the pouch is opened. A finger is inserted through the neck of the sac down into the oesophagus, putting the cricopharyngeus on stretch. A posterior vertical 4 cm myotomy of this muscle is then performed. The recurrent laryngeal nerves lie laterally and should not be endangered if the myotomy is performed in the midline posteriorly. The pharyngeal wall at the neck of the sac is closed and a drain is placed adjacent to the closure.

Surgery for malignancy of the larynx, pharynx and trachea

Much of the radical surgery for cancers of the larynx and hypopharynx has now been centralised in specialist units. Close cooperation is essential between



23.21 Branchial cyst and fistula. (a) A single incision over a cyst is usually adequate. (b) The opening of a branchial fistula must be circumscribed by an elliptical incision, and the dissection of the fistula is commenced through this incision. Access for the proximal dissection will be inadequate, and a second higher incision as marked will be necessary. (c) The fistula track passes between the carotid arteries to the tonsillar fossa. ⏎



23.22 The neck of a pharyngeal pouch is just above the cricopharyngeus, but the fundus of the pouch compresses the upper oesophagus. ⏎

the surgeon, radiotherapist and oncologist to plan the optimum treatment. Accurate preoperative staging is important. Radical mutilating surgery is justified if it offers the best chance of cure or of local control of the disease, but must not be undertaken when it can achieve neither and will merely add to the patient's distress. Postoperatively, the patient will need skilled rehabilitation and speech therapy. Regional centres specialising in this work will achieve better results, and most general head and neck surgeons in the UK are no longer performing the occasional major resection for cancer. This work is now totally outside the field of the general surgeon.[23] An isolated general surgeon in a developing country without access to referral facilities is unlikely to be in a position to undertake such an operation, and is even less likely to be able to offer the patient a reasonable expectation of a cure by surgery or be able to provide good rehabilitation.

However, general surgeons should be aware of the principles of these resections, if only to understand what has been done in a patient who is subsequently admitted under their care with related or unrelated pathology.

Laryngectomy

A horizontal incision is made through skin and platysma. The subsequent dissection will depend on whether the laryngectomy is to be combined with a neck dissection. The thyroid lobe on the side of the tumour is commonly removed with the larynx, and the strap muscles on this side are divided at their lower end and excised as part of the specimen. Thus, the larynx is mobilised laterally by a thyroid lobectomy dissection on one side and through the plane between the thyroid gland and the trachea on the other. Posteriorly, it must be separated from the oesophagus. Inferiorly, the trachea is transected and the distal end mobilised so that it can be brought out as an end tracheostomy, which is sutured to the skin. Superiorly, the suprahyoid muscles and the stylohyoid ligaments are divided and the hyoid bone is removed with the specimen. Removal of the larynx then leaves an anterior defect in the pharynx, which is closed. Various forms of partial laryngectomy with preservation of speech have also been developed, but these procedures are limited to specialised head and neck centres.

Laryngopharyngectomy

This more extensive resection is usually performed through an apron or transverse incision. One or both lobes of the thyroid are often included in the specimen and the resection is commonly combined with a neck dissection. The tracheostomy is established early in the procedure. The initial dissection is similar to that for a laryngectomy, but laterally the dissection is carried posteriorly, down to the prevertebral fascia, and the pharynx is drawn forwards as part of the resection specimen. Superiorly, the resection is above the hyoid, and the base of the tongue is transected leaving a hole into the oral cavity. When the operation is combined with an oesophagectomy, reconstruction is usually by using the stomach, which is pulled up through the posterior mediastinum after intra-abdominal mobilisation (see also Chapters 8 and 9). If only the proximal cervical oesophagus is included in the resected specimen, a free jejunal flap can be utilised as an alternative for reconstruction. This involves a microvascular anastomosis of the mesenteric pedicle of the jejunum onto the recipient vessels in the neck, and anastomosis of the jejunal tube proximally and distally to bridge the gap from the pharyngeal resection. If microsurgical skill is not available, then a tubularised pectoralis major flap can be used. This flap is a myocutaneous flap with a good blood supply.

SURGERY OF THE OESOPHAGUS

Surgery of the oesophagus is covered in greater detail in Chapters 8 and 9, which relate to the upper gastrointestinal tract. However, the approach to the cervical oesophagus is described below. Direct surgical access may occasionally be required for an impacted foreign body that cannot be removed endoscopically, for the open repair of a pharyngeal pouch or for the repair of trauma that is too severe to be managed conservatively. More commonly, surgery is required for an oesophagostomy or an oesophageal anastomosis. A cervical oesophageal anastomosis after oesophagectomy is a safer anastomosis, should the anastomosis leak, than an anastomosis within the thorax. For this reason, a more extensive oesophagectomy is sometimes preferred in order to site the anastomosis high up, in the neck. On other occasions, a more proximal tumour itself necessitates a cervical anastomosis.

Oesophagostomy is a permanent or temporary end stoma of the oesophagus. It allows drainage of swallowed saliva, preventing it from entering an area of oesophageal breakdown or, when there is a complete obstruction, pooling above it with threat to the airway. With the improvement in oesophageal stents, oesophagostomy is seldom necessary in malignant obstruction, but it still has a role in patients who have had a major failure of an oesophageal reconstruction or oesophageal destruction from caustic burns. In addition, such patients will require a feeding gastrostomy and drainage of the posterior mediastinal sepsis. Reconstruction can then be postponed until local conditions in the mediastinum have improved and the patient has recovered good physiological and nutritional status.

An oesophagostomy can also be a temporary solution in a long-segment oesophageal atresia that cannot be reconstructed in the neonatal period. It prevents saliva from entering the bronchial tree and also allows the baby to develop feeding skills while gaining weight through feeding via a gastrostomy, prior to major reconstructive surgery (see Chapter 27).

CERVICAL APPROACH TO THE OESOPHAGUS

A transverse skin crease incision at the anterior border of the sternocleidomastoid is made through the skin and platysma. The height of this incision will vary according to the level of the oesophagus to which access is required, but the level of the cricoid cartilage is most often appropriate. The deep cervical fascia is then incised along the anterior border of the sternocleidomastoid, which is retracted laterally. The thyroid is retracted medially and the middle thyroid veins and omohyoid are divided. The carotid sheath is retracted laterally and the inferior thyroid artery is ligated and divided. This plane between the thyroid and the carotid sheath takes the surgeon down to the prevertebral fascia, and the dissection should be safely lateral to the recurrent laryngeal nerve. However, the nerve is still in danger, in its groove between the trachea and the oesophagus, as the oesophagus is mobilised. It is therefore safest to identify the recurrent laryngeal nerve as it crosses the medial end of the inferior thyroid artery. Once identified, it can then be followed both up and down and safeguarded from injury.

The vertebral bodies of the cervical column can be approached anteriorly by using the same dissection as that described above for the oesophagus.

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Neurosurgical procedures for general surgeons

24

Hrishikesh Sarkar, Vignesh Sayee, Pradeep Balaji and Agnetia Vinoth

INTRODUCTION

In the ever-changing realm of global healthcare, the intersection between general surgery and neurosurgery is increasingly prominent, driven by the acute nature of neurosurgical conditions and variable access to specialised care. This chapter is designed to equip general surgeons with the essential knowledge and skills to manage neurosurgical emergencies when neurosurgical expertise is not available. This need is underscored by the prevalence of traumatic brain injuries (TBIs), spinal trauma, hydrocephalus, infections and intracranial haemorrhages/strokes, which may require immediate intervention in the absence of a neurosurgeon (see below). For instance, the management of TBIs might necessitate emergency burr holes for haematoma evacuation or elevation of skull fractures and scalp repair by general surgeons. This chapter aims to provide a foundational understanding of neurosurgical principles, diagnostic approaches and interventions, empowering general surgeons to navigate these complex conditions effectively. It fosters a collaborative approach to patient care, ensuring general surgeons can bridge the gap in neurosurgical emergencies and enhance patient outcomes, especially across diverse healthcare settings.

The following are clinical scenarios that warrant urgent neurosurgical intervention but that can be managed by a general surgeon:

- Scalp and calvarial trauma repair procedures
- Surgery for TBI
- Chronic subdural haematoma evacuation
- Acute hydrocephalus – emergency ventricular tap
- Brain abscess drainage
- Traumatic spine injuries – emergency spinal decompressive surgery
- Closure of open spinal dysraphism in neonates

MANAGEMENT OF SCALP AND CALVARIAL INJURY

Scalp and calvarial injuries frequently present in trauma settings and require careful attention by general surgeons. Prompt recognition and appropriate treatment are critical for preventing complications. A good understanding of scalp and calvarial anatomy, along with skilful management of these injuries, is crucial for optimal patient outcomes.

SCALP AND CALVARIAL ANATOMY

Scalp anatomy

The scalp consists of five layers: skin, connective tissue, aponeurosis, loose connective tissue and pericranium (collectively known as SCALP; Figure 24.1). The vascular supply is rich, with the main arteries being branches of the external carotid artery, including the superficial temporal, posterior auricular and occipital arteries. The venous drainage parallels the arteries and includes the superficial temporal, posterior auricular and occipital veins. The majority of the vasculature is within the subcutaneous layer.

Calvarial anatomy

The calvarium, or skullcap, comprises the frontal, parietal, occipital and temporal bones. It provides rigid protection for the brain and houses venous sinuses. The diploic space between the inner and outer tables of the skull bones contains marrow and contributes to the bone's blood supply, primarily via branches of the internal and external carotid arteries. Just under the bone there is a dura that overlies the arachnoid, pia and brain matter (see Figure 24.1).

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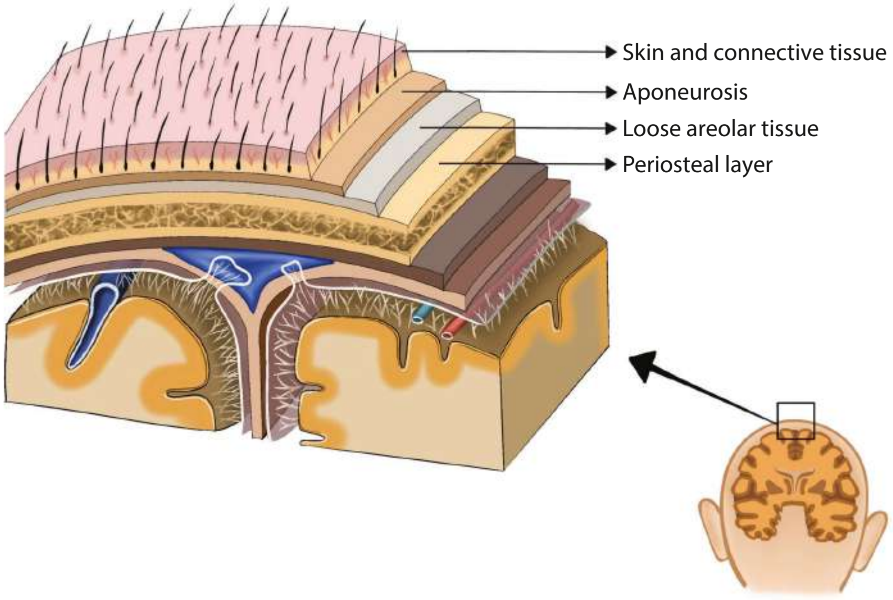


24.1 Schematic diagram of the anatomy of the scalp showing the skin, connective tissue, aponeurosis, loose connective tissue and pericranium. (Image by Mr Derrick Pradeep C from Grayscalart.) ⏎

DIAGNOSIS OF SCALP AND CALVARIAL INJURIES

Initial management

A detailed history and physical examination should be conducted, looking for lacerations, abrasions, contusions, haematomas and avulsions. The neurological status is assessed with the Glasgow Coma Scale (GCS). Signs of skull fracture or intracranial injury – such as Battle's sign, raccoon eyes or cerebrospinal fluid (CSF) otorrhoea/rhinorrhoea – should be noted.

Imaging techniques

While X-rays can reveal obvious fractures, they can miss subtle injuries. Computed tomography (CT) scans provide a comprehensive view of the skull, showing even minor fractures and intracranial pathology.

PRINCIPLES OF SCALP INJURY MANAGEMENT

Haemostasis

Bleeding from scalp wounds can be profuse due to the rich vascular supply. In children, this can lead to hypotensive shock. Immediate resuscitative measures may be needed. Direct pressure, followed by suturing with full thickness 2/0 or 1/0 Ethilon or staples, is effective for most bleeding. For avulsions or extensive injuries, more aggressive haemostasis, including ligation or cauterisation of vessels, may be necessary.

Debridement and closure

Debridement is critical and must balance the removal of non-viable tissue and foreign body such as dirt or gravel with the preservation of as much viable tissue as possible. Scalp lacerations are typically closed primarily with sutures or staples. For complex injuries, such as avulsions or large defects, tissue flaps or grafts may be required.

Infection prophylaxis

Antibiotics should be administered based on the degree of contamination and the presence of foreign bodies. Tetanus prophylaxis is also essential.

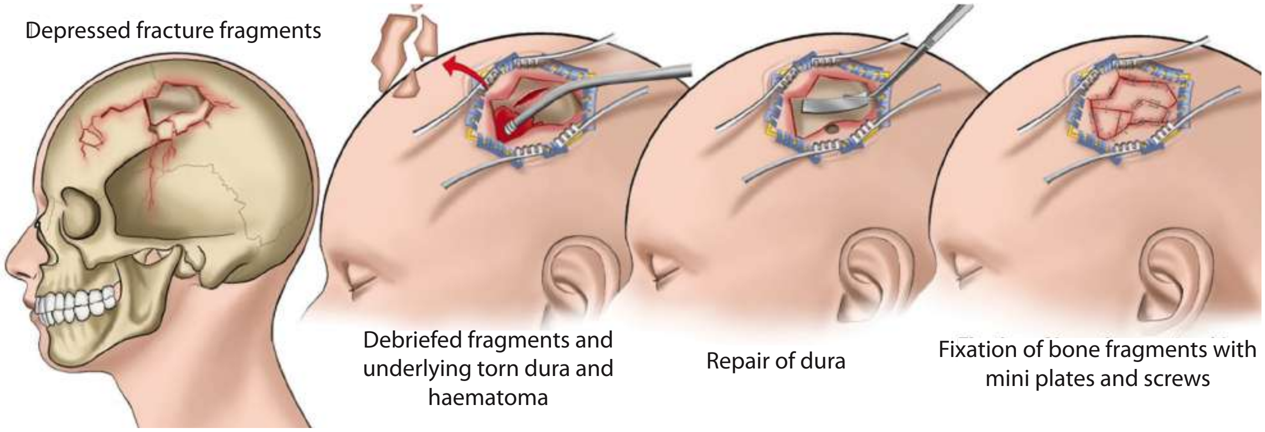
PRINCIPLES OF CALVARIAL INJURY MANAGEMENT

Non-operative management

Not all calvarial fractures require surgical intervention. Linear, non-depressed fractures without neurological deficit or overlying laceration can be managed with observation.

Operative management

Depressed fractures, especially those with overlying lacerations or signs of neurological compromise, require surgical intervention. The general surgeon should focus on elevation of the depressed fragments, debridement of the wound and watertight closure of the dura if the dura is breached and accessible.


Depressed fracture fragments
Debriefed fragments and underlying torn dura and haematoma
Repair of dura
Fixation of bone fragments with mini plates and screws

24.2 Schematic diagram of the elevation of a depressed fracture. Note, a burr hole is created adjacent to the fragment over the stable portion of the skull. (Image by Mr Derrick Pradeep C from Grayscalart.) ⏎

A simple dural tear can be repaired primarily. For complex cases or if dural tears are suspected, referral to a neurosurgeon is warranted.

POSTOPERATIVE MANAGEMENT

Postoperative care includes close monitoring for signs of infection, neurological deterioration and seizures. Prophylactic antibiotics and seizure prophylaxis may be considered based on the individual case.

SURGICAL TECHNIQUE FOR DEPRESSED FRACTURES

Preoperative planning is crucial and involves a thorough review of CT images to understand the fracture pattern and to plan the incision. Prophylactic antibiotics should be administered prior to making an incision, which may either utilise an existing defect or be fashioned to create a broad-based flap. Reflect the scalp flap carefully to avoid exacerbating any existing injury. Elevate bone fragments using an elevator (Figure 24.2), and inspect the dura for tears. Remove loose, small fragments of bone that are no longer viable. If the dura is intact and the brain is uninjured, the bone can be replaced. If the bone is contaminated or comminuted, plan for bone substitution with a synthetic material at a later date. Closure is typically performed in a single layer.

SURGERY FOR BRAIN TRAUMA

MECHANISMS OF BRAIN INJURY

Brain injuries are a significant concern in trauma care and can result from a variety of mechanisms, often classified as blunt trauma, penetrating injuries and blast injuries. Each mechanism has unique pathophysiological features and clinical implications.

PEARLS OF WISDOM

- Be prepared for blood loss. Intraoperative bleeding can be significant due to the vascular nature of the scalp and the potential for vascular injury.
- Control bleeding from the brain tissue using a low-power bipolar setting and ensure clear visualisation of the bleeding site with suction. Additionally, haemostatic agents, such as Gelfoam or Surgicel if available, can be utilised.
- Proactively manage potential seizures with appropriate antiepileptic drugs.
- Be aware of the risk of abscess formation in the postoperative period.
- Preoperative discussions with the patient should cover functional and cosmetic outcomes, including the potential need for further reconstructive surgery.

Blunt trauma

Blunt trauma to the head can occur during events such as vehicle accidents, falls or assaults. The impact causes the brain to move within the skull, potentially leading to bruising, tissue damage and haemorrhage. Two specific types of injury can result from blunt trauma: coup–contrecoup injuries and diffuse axonal injury (DAI).

Coup–contrecoup injuries Coup–contrecoup injuries are characterised by damage at the site of impact (coup injury) and on the opposite side of the brain (contrecoup injury). This occurs because the force of the impact causes the brain to collide with the internal surface of the skull and then rebound to strike the opposite side. These injuries often cause contusions and can be associated with skull fractures.

Diffuse axonal injury DAI is a type of injury that results from shearing forces that occur when the head is rapidly accelerated or decelerated, like in whiplash-type injuries. These forces lead to stretching and tearing of axons, which are the parts of nerve cells that conduct electrical impulses. DAI can lead to a widespread brain dysfunction because it usually involves injury to multiple areas of the brain, especially areas where the density of the brain tissue changes, such as the grey matter–white matter junction.

Penetrating injuries

Penetrating head injuries occur when an object, such as a bullet or a piece of shrapnel, breaches the skull and enters the brain. These injuries are particularly dangerous because they can lead to significant primary damage along the path of penetration and secondary damage due to bleeding, swelling and infection.

Blast injuries

Blast injuries are caused by explosions and are a particular concern in military conflicts and terrorist attacks. The initial blast wave can cause primary blast injuries that lead to diffuse brain damage without a visible head wound. Secondary injuries from flying debris can cause penetrating or blunt trauma. Additionally, the blast can lead to tertiary injuries if the individual is thrown by the force of the explosion, causing further blunt or penetrating trauma upon impact with another surface.

Primary versus secondary brain injury

Primary brain injury refers to the immediate damage caused by the trauma itself, such as the tearing of nerve fibres in DAI or tissue destruction in penetrating injuries. Secondary brain injury, which can be more insidious, refers to the subsequent damage that occurs in the minutes, hours and days following the initial injury. This includes a cascade of cellular processes leading to further neuronal damage and can be due to a variety of factors such as inflammation, increased intracranial pressure (ICP), hypoxia and infection.

The management of brain injuries requires a nuanced understanding of these mechanisms to tailor the treatment to the specific type and extent of injury. While some treatments can prevent or mitigate secondary brain injury, the initial focus is often on stabilising the patient and addressing any immediate threats to life.

CLINICAL ASSESSMENT IN BRAIN TRAUMA

In the setting of brain trauma, rapid clinical assessment is essential for guiding management and determining the need for further diagnostic imaging. The GCS and pupil examination are two of the primary methods used to assess the severity of brain injury at the bedside.

Glasgow Coma Scale

The GCS is the most widely used scoring system to describe the level of consciousness in a person following a brain injury. It assesses three aspects of a patient's responsiveness: eye opening, verbal response and motor response. The total score ranges from 3 (indicating deep unconsciousness) to 15 (a fully awake person). Eye-opening response is rated from 1 (no eye opening) to 4 (eyes opening spontaneously). Verbal response is scored from 1 (no verbal response) to 5 (oriented conversation). Motor response ranges from 1 (no motor response) to 6 (obeys commands). A GCS score of 8 or less signifies severe injury, a score of 9–12 denotes moderate injury and a score of 13–15 indicates mild injury. The GCS provides valuable information about the patient's neurological status and can guide urgency in management.

Pupil examination

Pupil examination provides critical information about brain function and potential herniation. Unequal pupils (anisocoria) or non-reactive pupils may indicate increased ICP and impending herniation, necessitating immediate intervention. Pupils are evaluated for:

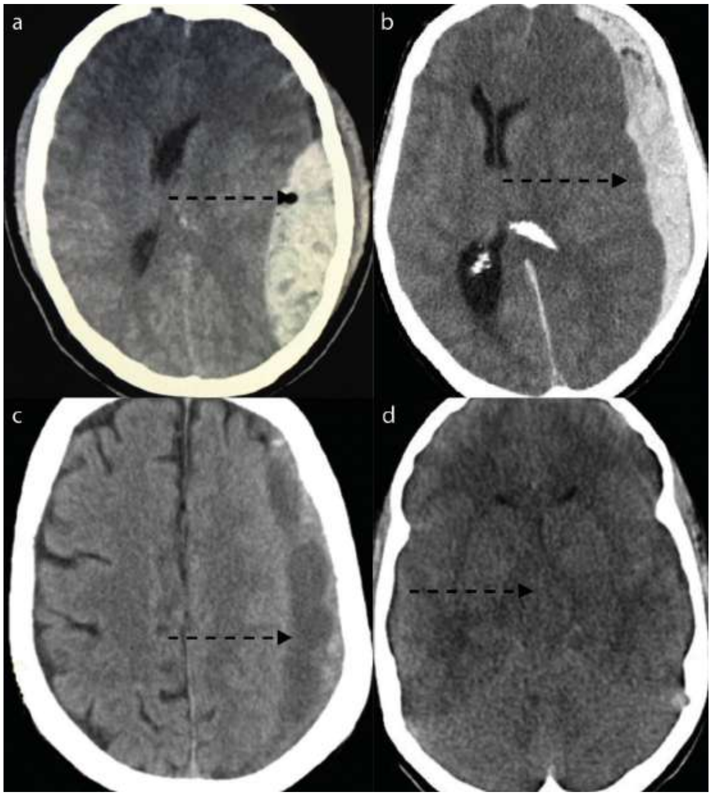
- *Size* – normal, dilated or constricted
- *Reactivity* – the presence or absence of reactivity to light
- *Symmetry* – whether both pupils are symmetrical in size and reactivity
- *Changes in pupil size and reactivity* – such changes can be early signs of deterioration in a patient with brain trauma and should be monitored closely

CT SCAN FINDINGS IN BRAIN TRAUMA

CT is the cornerstone of diagnostic imaging in brain trauma due to its wide availability, rapid acquisition time and detailed evaluation of acute intracranial pathology.

Epidural haematoma on CT

Epidural haematoma appears as a biconvex, or lens-shaped, hyperdense (bright) blood collection that typically does not cross suture lines due to the adherence of the dura to the sutures. It is most often associated



24.3 CT scan findings in TBI needing urgent surgical intervention. (a) Extradural haematoma. (b) Acute subdural haematoma. (c) Chronic subdural haematoma. (d) Severe diffuse brain swelling with obliteration of CSF spaces.⏎

with arterial bleeding, commonly from the middle meningeal artery, and requires prompt surgical evacuation, especially if symptomatic or causing significant mass effect (Figure 24.3a).

Subdural haematoma

Subdural haematoma (SDH) is visualised as a crescent-shaped hyperdense collection along the convexity of the cerebral hemisphere, just beneath the inner layer of the dura mater. SDHs can cross suture lines but not dural reflections such as the falx or tentorium. Acute SDHs are usually due to venous bleeding and can exert a mass effect on the brain, sometimes necessitating surgical drainage (Figure 24.3b).

Chronic subdural haematoma

Chronic SDH (CSDH) appears as a crescent-shaped hypodense area along the convexity of the cerebral hemisphere, causing varying degrees of midline shift. The density may vary due to the presence of layers of different-aged blood. The diagnosis is made based on clinical correlation with imaging findings (Figure 24.3c). (For more information, see the section 'Burr hole evacuation of chronic subdural haematoma'.)

Severe brain swelling

Severe brain swelling is indicated by diffuse enlargement of the brain on CT, with effacement (flattening) of the cerebral ventricles and sulci. The grey–white matter differentiation may become less distinct. In advanced cases, midline shift or herniation can be observed. These findings suggest a poor prognosis and may require medical, and potentially surgical, interventions to relieve ICP (Figure 24.3d).

Each of these CT findings has implications for patient management and potential surgical intervention. Understanding the CT characteristics of various TBIs is essential for general surgeons to make informed decisions in the acute management of brain trauma.

INDICATIONS FOR SURGERY IN BRAIN TRAUMA

Surgical intervention in the context of brain trauma is guided by a combination of clinical assessment and radiological findings. The decision to operate is a critical one, often made under time-sensitive conditions, and can have a profound impact on the patient's outcome. Emergency surgery is indicated for a large bleed with significant mass effect in a patient showing altered consciousness and/or focal weakness associated with pupillary dilatation. Examples of such large bleeds and severe brain swelling along with impending herniation syndrome are illustrated in Figure 24.3. CSDH that is associated with TBIs is managed differently and is covered extensively in the section 'Burr hole evacuation of chronic subdural haematoma'.

SURGICAL PROCEDURES FOR TBI

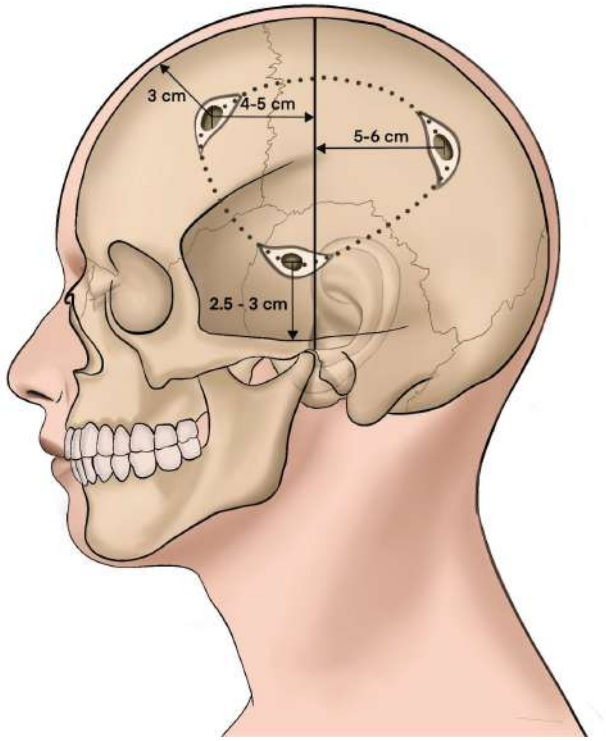
In the absence of a neurosurgeon, a general surgeon may need to perform life-saving procedures for patients with brain trauma using basic surgical equipment. Below are step-by-step guides to performing an exploratory burr hole and a decompressive craniectomy.

Exploratory burr hole

When a CT scan is not available, which is often the case in resource-limited settings or in certain emergency situations, an exploratory burr hole procedure may be indicated based on clinical judgement. This is typically done for patients who exhibit signs of increased ICP or an intracranial haematoma that is acutely life threatening. The following is a step-by-step guide to burr hole exploration, as illustrated in Figure 24.4.

Assessment and indications Conduct a thorough clinical assessment, including neurological examination (GCS score, pupillary response and focal deficits). Identify signs suggestive of a unilateral intracranial haematoma, such as unilateral dilated pupil, hemiparesis on the opposite side or a rapidly declining level of consciousness. Determine the most likely site of the haematoma based on clinical signs.

Preparation Obtain informed consent, explaining the emergency nature of the procedure and its risks due to the lack of imaging guidance. Assemble all necessary equipment: scalpels, periosteal elevators, a high-speed drill or perforator, a Hudson brace (Figure 24.5), bone rongeurs, suction, sterile drapes, gloves, gauze and suture material. Prepare the patient by positioning them supine with the head slightly elevated and immobilised. If the suspected haematoma is unilateral, the head should be rotated to the opposite side. Both sides may need to be explored. This procedure has to be done under general anaesthesia, as appropriate and available. In resource-constrained locations, only a Hudson brace may be available; therefore, it is important to be familiar with this life-saving equipment.



24.4 Schematic diagram of a burr hole exploration: location of exploratory burr holes. The burr holes should be away from the midline and may need to be placed bilaterally. (Image by Mr Derrick Pradeep C from Grayscalart.) ⏎

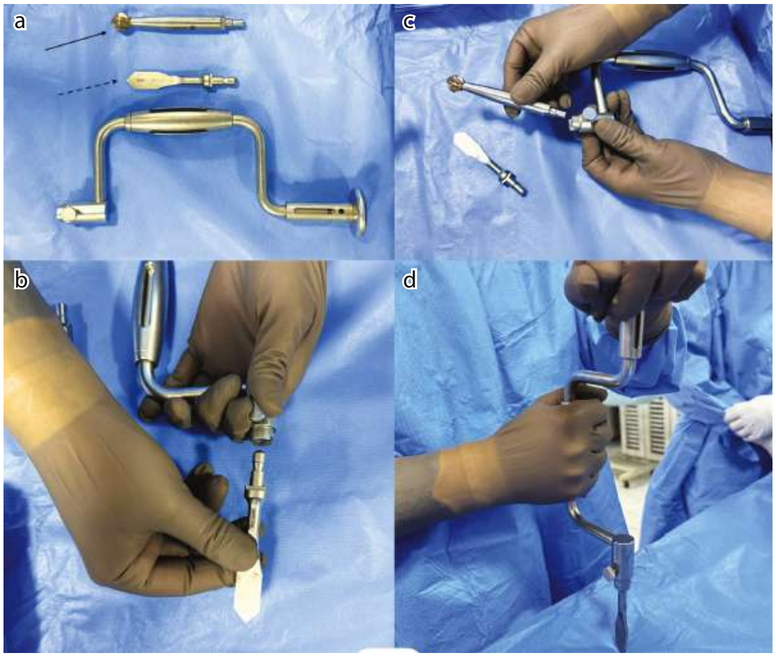
Incision Make three curvilinear incisions about 3–4 cm in length over the area of the skull, one each in the frontal, parietal and temporal regions as illustrated in Figure 24.4. The burr holes should be made using a high-speed drill or perforator to create a burr hole in the skull.

Attachment of the perforator blade Securely attach the perforator blade to the Hudson brace, ensuring a tight fit to prevent slippage during bone penetration (Figure 24.5).

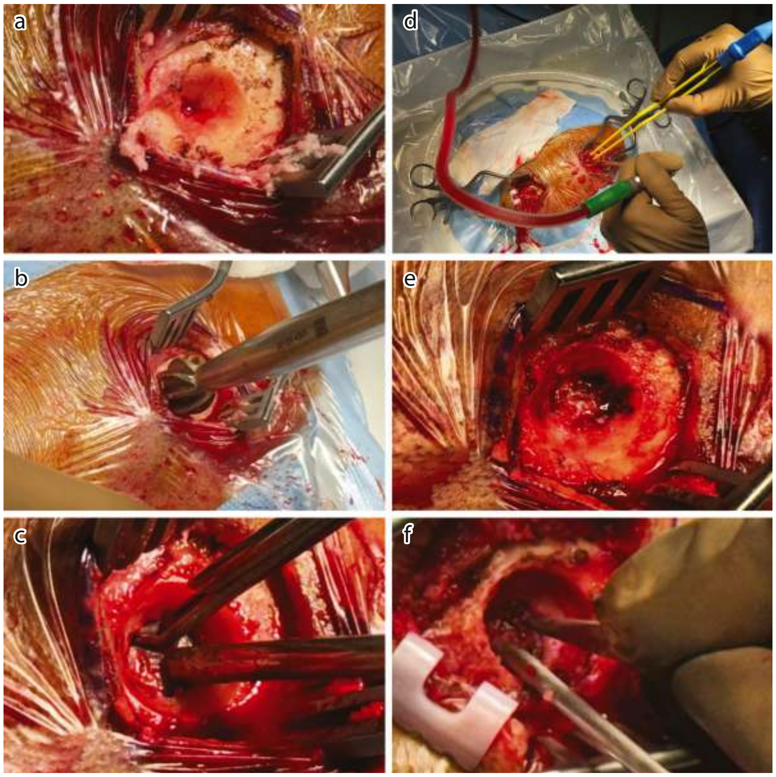
Initial penetration Apply gentle clockwise and anticlockwise movements with the brace while exerting pressure perpendicular to the skull's surface (Figure 24.5d). Gradually penetrate the outer layer of the cortical bone, taking care to maintain stability and avoid excessive force.

Continuous rotation Once initial penetration is achieved, initiate continuous rotation of the handle in one direction. Control the pressure exerted by the brace, ensuring it remains within safe limits to prevent injury and maintain accuracy.

Transition to burr Once the inner cortex is breached (Figure 24.5A), replace the perforator blade attachment with a burr designed to fit snugly into the burr hole. Continue rotating the brace in a controlled



24.5 Hudson brace: parts and components. (a) Straight arrow: burr. Dotted arrow: perforator blade. (b, c) How to attach the blade and perforator to the handle. (d) Correct way to handle the Hudson brace. The force over the handle should not be more than that of the surgeon's hand. Beware of plunging suddenly. ⏎



24.5A Intraoperative images: the creation of a burr hole. (a) After perforation of the inner table. (b) Application of the burr. (c) Kerrison rongeur to nibble the edges of the burr hole. (d) Bipolar coagulation of the dura. (e) Coagulated dural surface. (f) Dural incision. ⏎

manner to remove surrounding bone tissue until the desired periosteal layer is reached. This layer appears similar to the shell of an egg and can be gently lifted with the help of a dissector to expose the dura mater.

Visualisation and confirmation Throughout the procedure, irrigate the surgical site and use suction as needed to maintain a clear field of view. Regularly inspect the layers of the skull to ensure accurate progress and avoid inadvertent damage.

Dural opening and evacuation Once the skull is penetrated, inspect the dura mater. It may appear tense and bluish if a subdural haematoma is present or may bulge outwards if pressure is high. Make a cruciate incision in the dura to expose the underlying brain. If a haematoma is present, it may start to extrude spontaneously. The dural incision should be made with a No 11 blade. The blade strokes should be gentle and incise through the layers of the dura gradually. If the haematoma does not extrude spontaneously, gently explore with a blunt instrument such as a dissector or a suction tip.

Evacuation and closure Gently evacuate the haematoma using suction and irrigation and close the scalp incision in two layers.

Postoperative care Monitor the patient closely for changes in neurological status and signs of further intracranial bleeding or infection. Keep the patient in an intensive care unit setting if available, with frequent neurological checks and supportive care.

PEARLS OF WISDOM

- Always prepare for the possibility of not finding a haematoma and having to create additional burr holes if you have no access to CT imaging.
- Have blood products ready for transfusion in the case of significant blood loss.
- If the patient's condition allows, perform bilateral burr holes to rule out contralateral haematomas.
- Proceed with caution, as blind exploration can lead to inadvertent damage to the brain or its vasculature.
- Patients should be referred to a neurosurgical facility as soon as possible.
- Adhere to proper positioning and stabilisation techniques to optimise surgical access and patient safety.
- Utilise preoperative imaging and meticulous surgical marking to ensure accurate placement of the burr hole. Avoid placing the burr hole over the midline, fractured/unstable bone or areas where large venous sinuses are located.
- Maintain precise control over the application of force and rotation during bone penetration to minimise the risk of complications.
- Control bleeding from the bone edges using bone wax and coagulate any dural surfaces with bipolar cautery set to not more than 25 W.

Decompressive craniectomy

Decompressive craniectomy is a surgical intervention performed to alleviate increased ICP by removing a portion of the skull, usually the size of the palm of a hand. This procedure facilitates brain expansion, preventing secondary damage due to compression. Following removal of the bone flap, the dura mater is typically left open to accommodate brain swelling. The bone flap may be kept in an abdominal wall 'pocket', inserting the bone deep to the skin. The bone segment can be replaced later after a few months for a reconstructive procedure. Postoperatively, patients require meticulous monitoring for complications such as haemorrhage, infection and cerebral oedema.

In some situations, after addressing the cause of raised ICP, the brain becomes lax and pulsatile. The bone flap may be replaced. This is called a craniotomy, whereby the bone flap is replaced and secured back into its original position with plates and screws. For practical reasons, the decision to replace the bone flap can be taken after consultation with a neurosurgeon.

Indications for decompressive craniectomy are either severe brain swelling and mass effect that is not responsive to medical management or both of the following:

- *Large haematomas* – extradural haematoma, subdural haematoma or brain contusions causing a midline shift as demonstrated on CT scan

- *Signs of herniation* – signs of raised ICP, including headache, nausea, vomiting, papilloedema and altered mental status

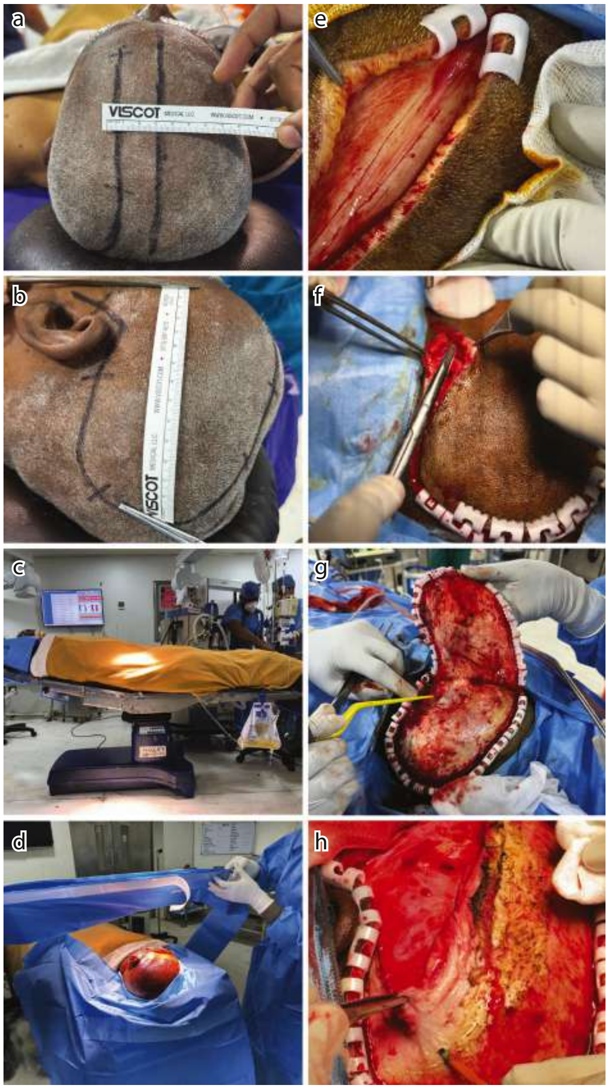
The following is a step-by-step guide for performing decompressive craniectomy.

Preparation As with the preparation of a patient for a burr hole, confirm the location of the intracranial pathology and prepare the surgical field following aseptic techniques.

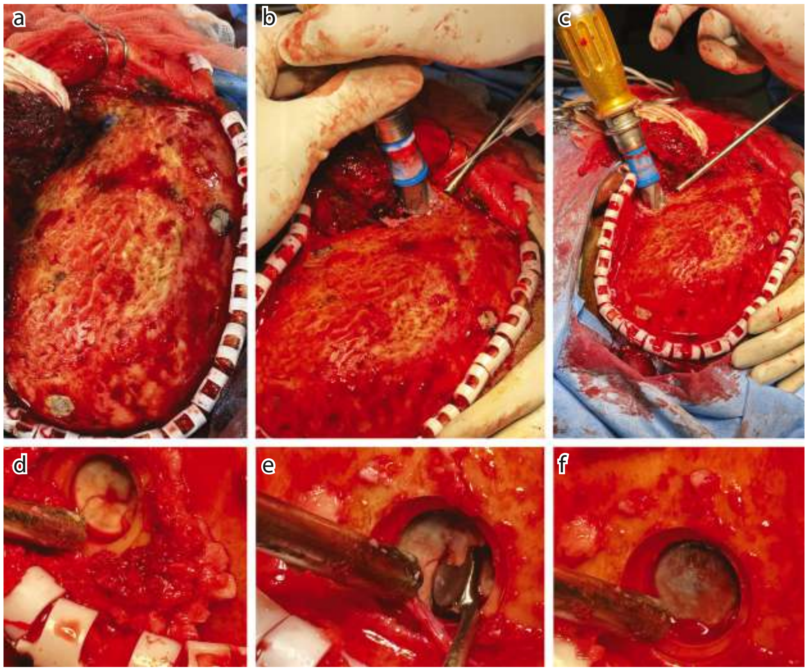
Positioning and scalp incision (Figure 24.6) After head shaving, position the patient such that the head is kept elevated above the heart and turned to the contralateral side by 60–70°, supported on a ring. Midline marking is done with a surgical marker. Plan a large, 'reverse question mark-shaped incision', starting just above the zygomatic arch, close to the tragus and extending superiorly in front of the ear, curving over the hemisphere convexity. The incision should stay at least 3.0 cm away from the midline, marked previously. This is to avoid the iatrogenic injury and catastrophic injury that can happen to the superior sagittal sinus. After this, the surgical area is cleaned with betadine surgical scrub three times, followed by with alcohol-containing solution another three times. Finally, betadine solution is used to paint the area. The skin is infiltrated all along the skin incision using 30 mL of solution prepared by diluting 15 mL of 1% lignocaine with adrenaline (1:200,000) with 15 mL saline, achieving a 0.5% concentration. Anaesthetists need to be consulted for this dosing and alerted for probable hypertensive response. Plain lignocaine is to be used if there are contraindications for adrenaline such as pre-existing cardiac disease. The area is draped such that its lower falling edge from the wound falls into a collection bucket. This helps keep the operative area clean. The incision is taken through the skin, subcutaneous tissue and galea to the level of the pericranium, and the scalp flap is reflected, exposing the temporalis muscle and the skull. Serially stacked small artery clips can be applied to the scalp edges on the galeal layer to reduce bleeding. Alternatively, if available, Cushing's clips or Raney's clips can also be utilised.

The underlying temporalis muscle is also lifted off the bone with monopolar coagulation to expose the temporal bone. The scalp flap, together with the temporalis muscle flap, is reflected and held with rubber bands sutured using 1/0 silk or extendable fish hooks. This exposes the entire frontal, parietal and temporal calvarium.

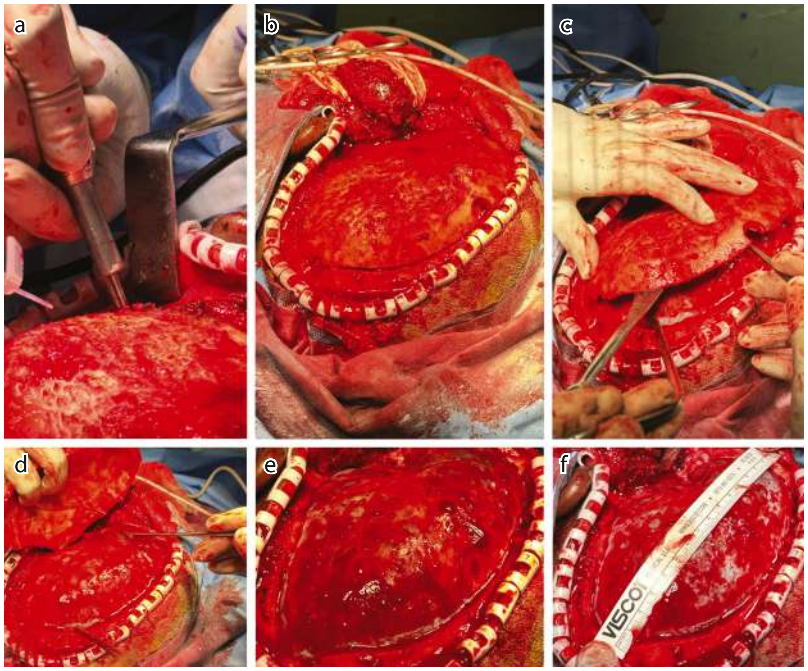
Creating the bone flap (Figures 24.7 and 24.8) Burr holes are created either as outlined in Figure 24.5A using a Hudson brace or, when available, by using a mechanised perforator. Use the high-speed drill to create burr holes around the planned craniectomy site. Then, using the craniotome or the drill, connect these burr holes to fashion the bone flap, not less than 11 cm in diameter. Alternatively, multiple burr holes can be made close to each other, so that a dissector along with a Gigli saw can pass through across the burr holes. Care should be taken not to injure the underlying dura or brain, especially



24.6 Intraoperative images: steps in a left-sided decompressive craniectomy (I). (a) Reverse question mark flap 3.0 cm from the midline. (b) Flap should measure at least 12 cm in diameter. (c) Head in elevated position to reduce brain swelling. (d) Head turned to the opposite side. (e) Scalp incision: haemostasis with Raney's clips and finger pressure. For scalp infiltration before incision, use 30 mL of solution prepared by diluting 15 mL of 1% lignocaine with adrenaline (1:200,000) with 15 mL saline, achieving a 0.5% concentration. (f) Dissection of the superficial temporal artery and exposure of the temporalis fascia. (g) Elevation of scalp flap. (h) Elevation of the temporalis muscle. ⏎



24.7 Intraoperative images: steps in a left-sided decompressive craniectomy (II). (a) Marking of the proposed burr hole sites with monopolar. (b, c) At least four burr holes each in the frontal (2.0 cm posterior to the supero-lateral orbital rim), temporal, parietal and close to the coronal suture are placed. (d–f) Sequential removal of the thin periosteal layer and exposure of the dura. ⏎



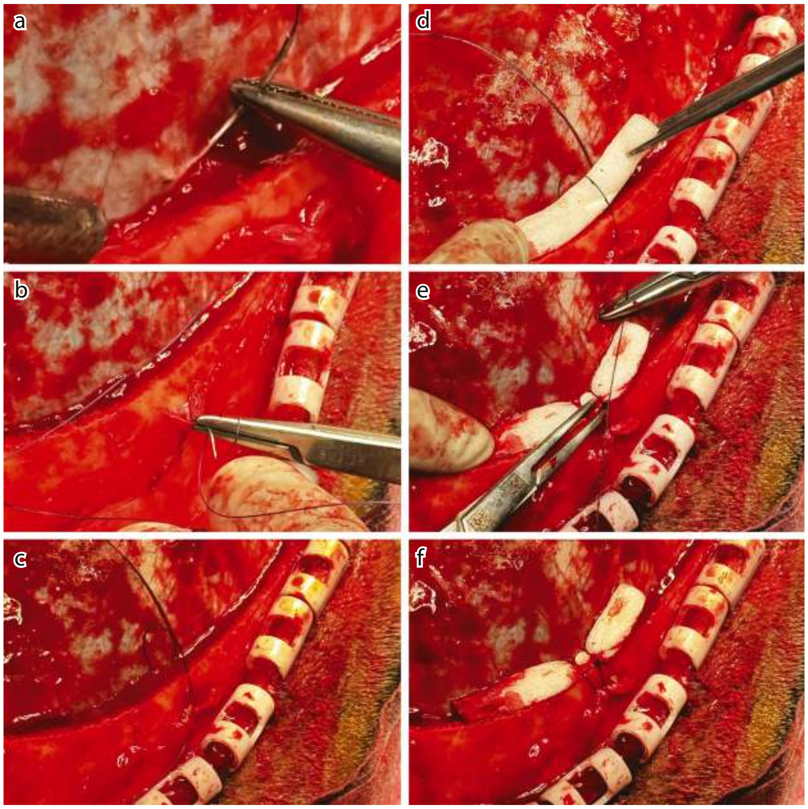
24.8 Intraoperative images: steps in a left-sided decompressive craniectomy (III). (a) A craniotome is being utilised to connect the burr holes all around to fashion a flap. (b) Disconnected bone flap. (c) Elevation of bone flap ensuring no breach of dura. (d–f) Dura is exposed; this is tense and discoloured. ⏎

while passing the number 1 Penfield dissector from one burr hole site to another. Both ends of the Gigli wire are held and the intervening bone flap can be 'sawed' off. Once all of the cuts between the burr holes are made, the bone flap is removed and the dura is exposed. Again, due care is required while elevating the bone flap, as the underlying dura can be adherent to the bone. Any undue or excessive pulling away movements of the bone flap off the brain, although enticing and easy, should be avoided.

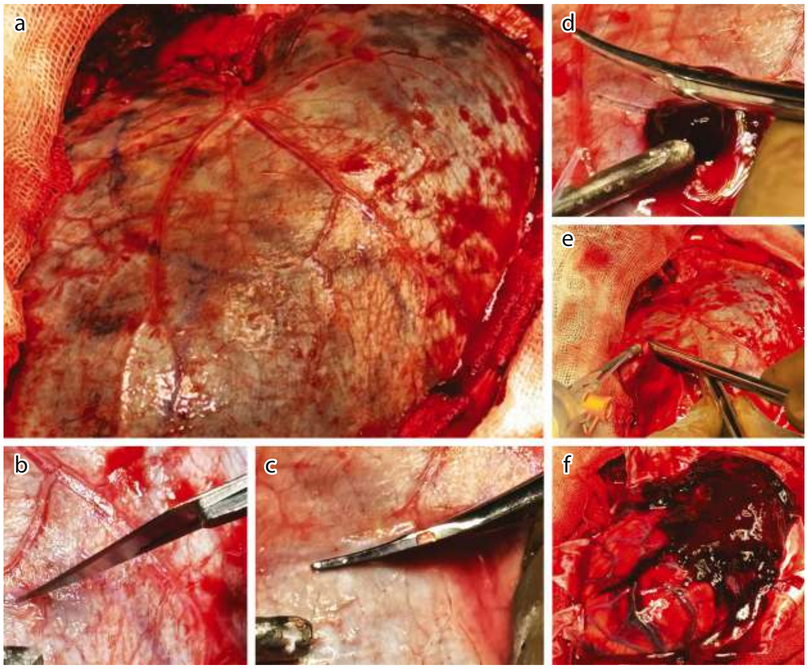
Hitching of dura and the dural opening (Figures 24.9 and 24.9A) Hitching of the dura involves securing the dura mater to the overlying bone with 3/0 Vicryl sutures to prevent its retraction during surgery. This technique is used to stop extradural venous bleeding, which can be profuse, both intra- and post-operatively. It is a life-saving complication-avoiding manoeuvre that can be utilised during craniectomy or craniotomy. This is illustrated in Figure 24.9.

Dural opening The dura should be coagulated thoroughly with bipolar coagulation. The dural opening is marked with the surgical marker as a large curvilinear incision based on the skull base. Using either a No 11 or No 15 blade, an initial small opening, measuring 1.0 cm in length, is made in either the frontal region anteriorly or the temporal region inferiorly, depending on the location of the haematoma. Any incision along the Sylvian region should be avoided (see Figure 24.9A). Gentle, soft strokes should be made, layer by layer with the dominant hand, gradually exposing the underlying haematoma or the contused brain. Inadvertent injury to the underlying brain should be avoided. Once the dural incision is completed, a toothed Adson should be used to lift the dural edge to insert non-pointed scissors over a cotton pattie. The underlying haematoma will extrude out spontaneously if it is under severe pressure. The dural incision is progressively lengthened to complete the first part of the dural opening, which is curvilinear. A sizeable amount of clotted blood will drain while doing so and the brain will appear to become lax. Next, a few radial incisions up to the bone edges are made to enable further haematoma expulsion, and the brain expansion and the resultant dural flaps are inverted to expose the brain.

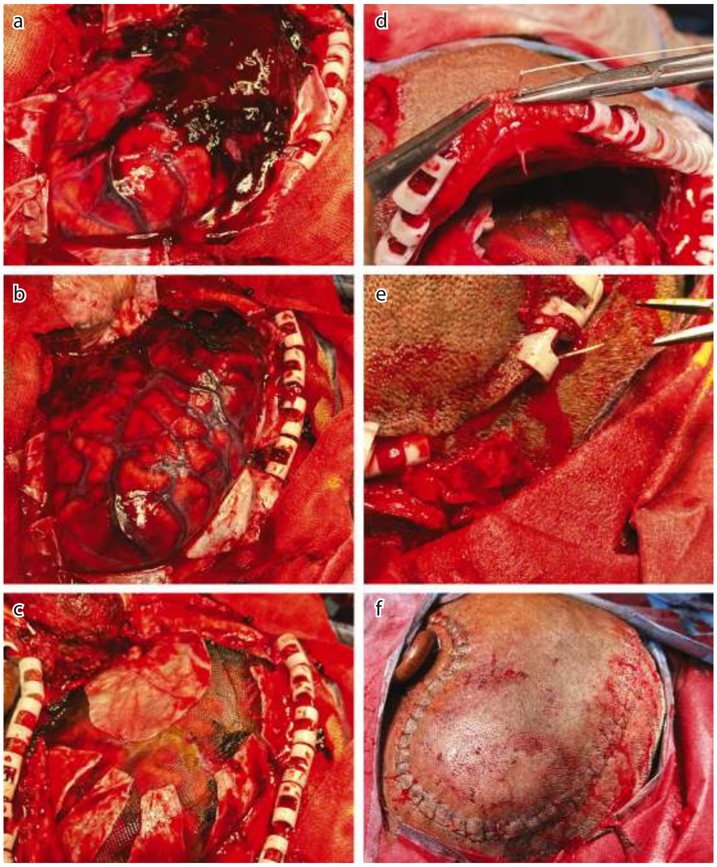
Decompression Ensure that enough bone has been removed to allow the swollen brain to expand without constriction. Remove the blood clots gently with low-powered suction, irrigation and dissectors. Avoid aggressive manipulation of the brain and vessels. The bleeders that can be visualised can be controlled with low-power bipolar coagulation (15 W) and irrigation. A large sheet of Surgicel (oxidised cellulose) or a wet Gelfoam (gelatin sponge) can be layered over the exposed brain surface to tackle surface bleeding. The venous bleeders from the bony edge and underneath can be controlled with bone wax or additional hitch stitches (Figure 24.10a–c).



24.9 Intraoperative images: technique to demonstrate 'hitching' of the dura with 3/0 Vicryl. This is important to reduce and prevent an extradural bleed under the bone edges. (a) Only the outer layer of dura is engaged with the needle. (b) Stable soft tissue bite is taken. (c) A loop is created within which a Gelfoam is placed. (e–f) The knot is tightened sequentially. ⏎



24.9A Intraoperative images: steps in a left-sided decompressive craniectomy (IV). (a) Curvilinear dural opening marked with a surgical marker based on frontal and temporal regions. (b) Dural incision with No 11 blade. (c–e) Incision extended with scissors preserving the underlying brain and vessels. (f) After completion of wide durotomy, severely swollen brain and underlying subdural blood clot is visible. ⏎



24.10 Intraoperative images: closure in decompressive craniectomy. (a) The entire swollen brain surface and the subdural blood clots are exposed. (b) Removal of the blood clots. (c) Replacement of the dural folds over the surgically covered brain. (d, e) Two-layered closure is required to prevent leakage. Note, an inside galeal layer is closed with 2/0 Vicryl. (f) Finally, the skin is closed with interlocking 2/0 Ethilon. ⏎

Haemostasis and closure After ensuring adequate decompression and haemostasis, leave the dura open to accommodate brain swelling. The scalp is then closed in layers, without replacing the bone flap. The subcutaneous layer and the galeal layer are taken together simultaneously with absorbable Vicryl 2/0 sutures, and the skin is closed with 2/0 or 1/0 non-absorbable nylon sutures or staplers. A surgical drain with 10–12 size can be placed under the skin flap without negative pressure and anchored to the underlying scalp. The bone flap can be stored subcutaneously in the abdomen or cryopreserved for later cranioplasty (Figure 24.10d–f).

MONITORING FOR COMPLICATIONS AND POSTOPERATIVE MANAGEMENT

Haemorrhage

Continuous monitoring Regular CT scans may be warranted to monitor for re-accumulation of blood or a new haemorrhage postoperatively.

Vital signs Monitor blood pressure closely, as hypertension can exacerbate bleeding, while hypotension can worsen cerebral ischaemia.

Drain output If a drain is placed, monitor the output both for quantity and for signs of fresh bleeding.

Sedation and ventilation Sedation and ventilation as per intensive care unit protocol is generally recommended for the first 72 hours to prevent bleeding and further swelling. An early tracheostomy may hasten the weaning and neurological recovery process.

Swelling

Intracranial pressure Flap fullness is often indirect evidence of ICP. A lax and pulsatile flap means that the ICP is under control, while a tense and non-pulsatile flap generally indicates a pathological ICP.

Neurological exams Frequent neurological exams can provide early signs of increased ICP, such as decreasing level of consciousness or new pupillary changes. Since the patient is sedated, assessing consciousness level may not be accurate. One has to rely on either pupils or a repeat CT. Conventionally, a repeat CT is done within 24 hours in the postoperative period and at least once before weaning and tracheostomy.

Osmotherapy Utilise mannitol or hypertonic saline to control cerebral oedema as indicated. A common starting dose of mannitol for an adult may be 0.5–1 g/kg of body weight, administered as a single intravenous infusion over a period of 30–60 minutes. This dose may be repeated every 4–6 hours as needed based on the patient's response and the level of ICP. The dose needs to be tapered over 3–4 days to prevent rebound cerebral oedema.

It is recommended to avoid what is termed the '6Hs': hypoxia, hypotension, hyperthermia, hyperglycaemia, hypoglycaemia and hypercarbia. All of these can lead to secondary brain injury.

Infection

An aseptic technique is crucial during any dressing changes or drain management.

Temperature monitoring Monitor for fever, which may be a sign of infection. It is important to have a low threshold for suspecting meningitis.

Seizures

Seizure prophylaxis with antiepileptic drugs may be indicated in the immediate postoperative period. The usual starting dose of levetiracetam by injection for adults is 500 mg twice daily (or 250 mg twice daily for older patients). This dose can be gradually increased by 500 mg every 2 weeks until the optimal dosage is reached, usually ranging from 1,000 to 3,000 mg per day, taken in divided doses. For paediatric patients (children and adolescents), the initial dose is typically lower and is based on body weight. A common starting dose for children aged 4 to 16 years is 10 mg/kg twice daily.

Supportive measures Elevating the head of the bed to 30° can reduce ICP, and ensuring adequate oxygenation and ventilation is essential for supporting brain function.

Pain management and comfort measures Administer analgesics as needed, balancing pain control with the ability to perform neurological assessments. Avoid strong opioids that could impair consciousness and wakefulness.

Non-pharmacological measures Employ non-pharmacological measures such as repositioning, massage and the use of cooling/warming blankets as appropriate. Early nutritional assessment and support are vital for promoting healing and preventing complications. Implement measures for deep vein thrombosis prophylaxis, such as mechanical compression devices or pharmacological agents, when the risk of bleeding is low. Regular changes of head position are also needed to prevent pressure-associated necrosis of the scalp flap.

PEARLS OF WISDOM

- Brain haemostasis
  - Gentle handling: the brain tissue is delicate; always handle it gently to prevent additional injury and bleeding.
  - Bipolar coagulation: utilise bipolar electrocautery for pinpoint haemostasis. Avoid monopolar cautery near the brain tissue to prevent inadvertent damage.
  - Haemostatic agents: have a variety of haemostatic agents ready, if available, such as oxidised cellulose (Surgicel) and gelatin sponge (Gelfoam), which can be applied to bleeding surfaces.
- Adequate lighting
  - Visibility: ensure good visibility with adequate lighting and assistance. The use of headlamps and focused operating room lights can significantly improve operative field visualisation.
- Suction
  - Controlled suction: use suction carefully to avoid damaging brain tissue. Keep the suction tip visible at all times and use it judiciously.
  - Intermittent suction: practise intermittent suction to prevent continuous negative pressure on the brain tissue, which can lead to further injury.
- Patties on the brain
  - Protection: use surgical patties (soft absorbent textile pads) to protect the brain tissue when retracting or working nearby. They provide a soft barrier between instruments and the cortex.
  - Count: always count the patties before, and after, the procedure to ensure none is left within the operative field.
- Brain bulge management
  - Osmotherapy: administer mannitol or hypertonic saline to reduce cerebral oedema if the brain starts bulging out of the operative site.
  - Adjust anaesthesia: work with the anaesthetist to ensure adequate anaesthesia depth, which can help reduce brain swelling.
- Bleeding management
  - Pressure application: if bleeding is encountered, applying pressure with a patty can often control it while other measures are taken.
  - Ready resources: have additional resources, such as extra suction, haemostatic agents and blood products, readily available.
- Be ready to quickly close the scalp
  - Rapid closure: if the situation becomes untenable, be prepared for a rapid closure.
- Scalp closure: ensure that the scalp is closed without too much tension to promote healing and prevent dehiscence.

BURR HOLE EVACUATION OF CHRONIC SUBDURAL HAEMATOMA

INTRODUCTION

CSDH is a common neurosurgical condition that is often seen in older people and in individuals on anticoagulation therapy. It typically presents weeks to months after a minor head injury, sometimes even after one that has been forgotten by the patient. For a general surgeon, recognising the emergency indications for surgical intervention in the case of a CSDH is imperative. While many patients with CSDH can be managed electively, certain clinical scenarios necessitate urgent surgical drainage to prevent morbidity and mortality. The emergency indications are as follows:

- *Rapid neurological decline associated with midline shift* – any rapid deterioration in the patient's level of consciousness or a significant decline in the GCS score necessitates immediate intervention.
- *Pupillary changes* – anisocoria (unequal pupils), particularly a fixed and dilated pupil on the side of the haematoma, is an ominous sign of increased ICP and impending herniation.
- *Hemiparesis* – the development or worsening of weakness on one side of the body indicates increasing pressure on the motor cortex and requires urgent decompression.

By doing a simple burr hole evacuation, a life can be saved. The goal is to alleviate mass effect on the brain by evacuating the haematoma, thus restoring normal cerebral function and preventing further neurological decline.

CT DIAGNOSIS

A CT scan of the head is the diagnostic modality of choice for CSDH. On CT, a CSDH appears as a crescent-shaped hypodense area along the convexity of the cerebral hemisphere, causing varying degrees of midline shift (Figure 24.3c). The density may vary due to the presence of layers of different-aged blood. The diagnosis is made based on clinical correlation with imaging findings.

STEPS FOR BURR HOLE EVACUATION

Preparation

Obtain informed consent after explaining the risks and benefits of the procedure. Perform a preoperative CT scan to localise the haematoma and plan the burr hole site. Local anaesthesia with sedation or general anaesthesia can be used depending on the patient's condition and the surgeon's preference.

Positioning and incision

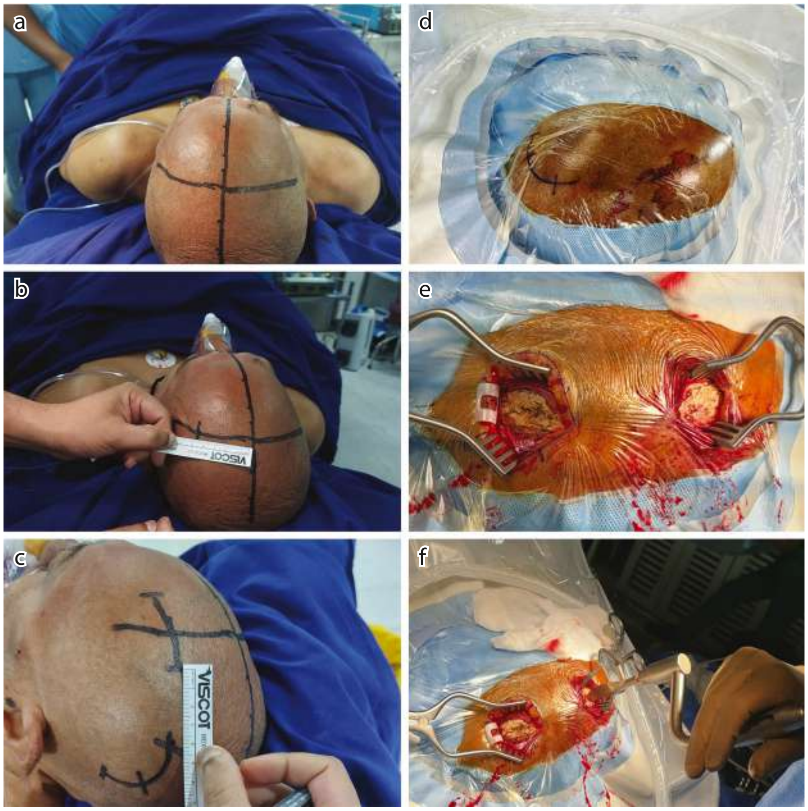
Initially, keep the head in a neutral position. Mark the midline and the coronal suture with a surgical marker. Next, mark two incisions: the first one at the coronal suture measuring about 4 cm, at least 5 cm away from the midline, and the second one at the level of parietal eminence, which could be optional. Rotate the head by 60–80° to the opposite side of the haematoma and support on a head roll or surgical rolls. The shoulder can be elevated with a sandbag. The operative field area should be cleaned, draped and infiltrated with local anaesthetic (Figure 24.11a–d).

Burr hole

Use a drill to create a burr hole in the skull. Start with a small bit to penetrate the outer table and enlarge it with a larger bit. Take care to avoid penetrating the dura with the drill. This is discussed in detail in the previous section (see Figures 24.5, 24.5A and 24.11e, f).

Dural opening

Carefully incise the dura, after coagulation with a low-power bipolar set on 25 W, with a No 11 blade layer by layer. This shoud begin in the centre of the burr hole and extend radially until the bone edges are reached, in a cruciate manner. Following this,



24.11 Intraoperative images: steps for burr hole evacuation of chronic subdural haematoma. (a–d) Curvilinear skin incision marking two burr holes, at least 5 cm away from the midline. (e) Exposure of the skull. (f) Hudson brace perforator being used to create an initial entry. ⏎

coagulate the dural flaps. Ensure extradural haemostasis (Figure 24.12a–c).

Evacuation

Gently evacuate the haematoma using gentle irrigation. Initially, a large amount of blood and clots will evacuate; however, this gradually reduces and the effluent from the irrigation will become clear. The clear effluent from the posterior burr hole following irrigation through the anterior burr hole marks the end of the evacuation process (Figure 24.12d).

Haemostasis

Achieve haemostasis within the burr hole using bipolar coagulation and haemostatic agents, as necessary.

Drain

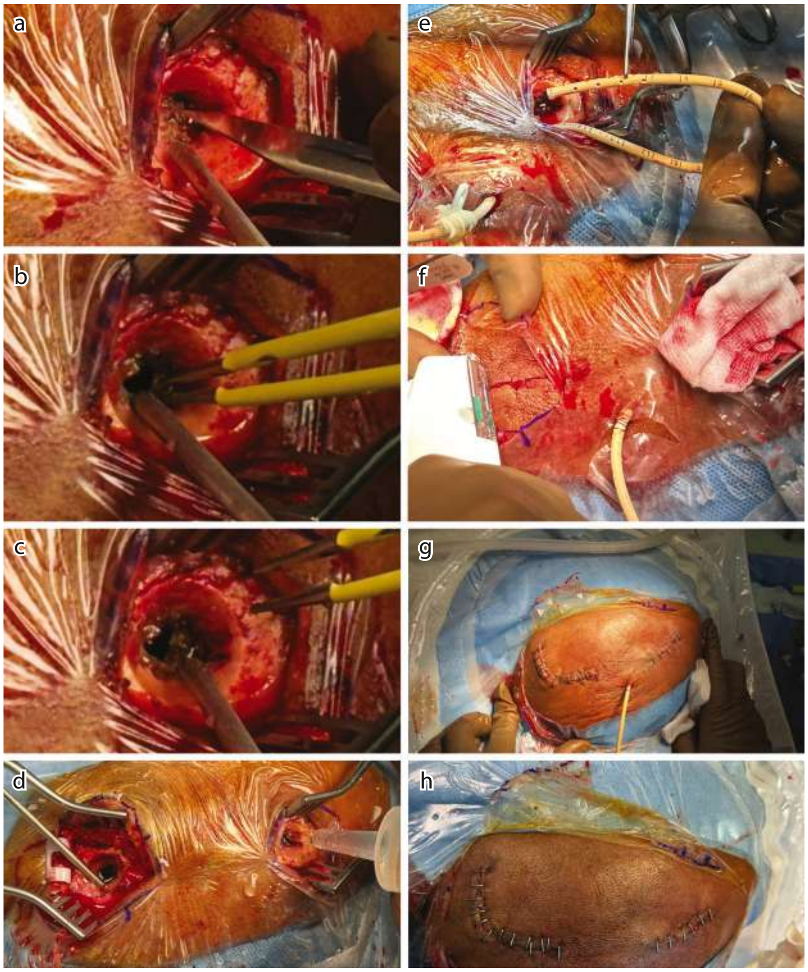
Place a subdural drain (infant feeding tube size: 6/8 French) to prevent re-accumulation of the haematoma. The drain is typically left in place for 24–48 hours (Figure 24.12e–g).

Closure

Close the skin with sutures or staples (Figure 24.12h).

POSTOPERATIVE CARE

Postoperatively, monitor the patient's neurological status and check for signs of re-accumulation or infection. Repeat a CT scan within 24–48 hours to ensure that the haematoma has been adequately evacuated and to assess for any acute re-accumulation. Manage pain with appropriate analgesics and maintain the head end of the bed flat for the first 2–3 days. Remove the drain as planned, usually after 24–48 hours if there is no significant re-accumulation.



24.12 Intraoperative images: steps for burr hole evacuation of chronic subdural haematoma. (a) Dural incision. (b) Coagulation of the dura. (c–d) Irrigation and evacuation of liquid clots until the effluent is clear. (e–h) Drain placement and closure. ⏎

PEARLS OF WISDOM

- Always confirm the side of the haematoma preoperatively to avoid wrong-site surgery.
- During evacuation, avoid aggressive suction or irrigation that can cause cerebral cortex damage.
- Be mindful of air entering the subdural space, which can lead to tension pneumocephalus.
- A postoperative headache is common and can be managed with analgesics; however, be vigilant for headache that worsens, which can indicate re-accumulation or complications.
- Bed rest for 3 days is recommended.

EMERGENCY EXTERNAL VENTRICULAR DRAIN FOR ACUTE HYDROCEPHALUS

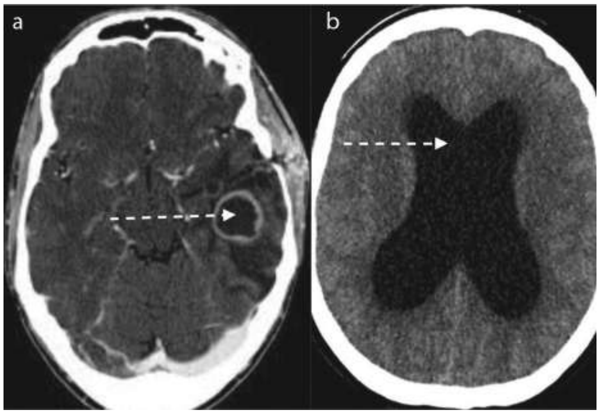
Introduction

An external ventricular drain (EVD) is an emergency neurosurgical procedure performed to alleviate acute hydrocephalus, a condition characterised by an abnormal accumulation of CSF within the ventricles of the brain, leading to increased ICP. The need for an emergency EVD arises in scenarios such as central nervous system infections with hydrocephalus, hypertensive intraventricular haemorrhage and tumour-associated hydrocephalus, where swift action can be life-saving (see Figure 24.13a). For general surgeons, understanding the indications and being aware of the technique of EVD placement are essential, particularly when neurosurgical expertise is not readily available. The diagnosis of acute hydrocephalus is based on the CT scan demonstrating massive dilatation of the ventricular system with periventricular ooze (Figure 24.13a).

Indications

Acute hydrocephalus requires prompt EVD placement when it is associated with:

- Worsening consciousness or a rapid decline in neurological function
- Radiological evidence of ventricular dilation with or without the presence of an intraventricular haemorrhage
- Signs of raised ICP, including headache, nausea, vomiting, papilloedema and altered mental status



24.13 CT brain scan. (a) Massive acute hydrocephalus. (b) A left temporal abscess (discussed in the section 'Tapping of a cerebral abscess').

Steps for an EVD placement

Preparation

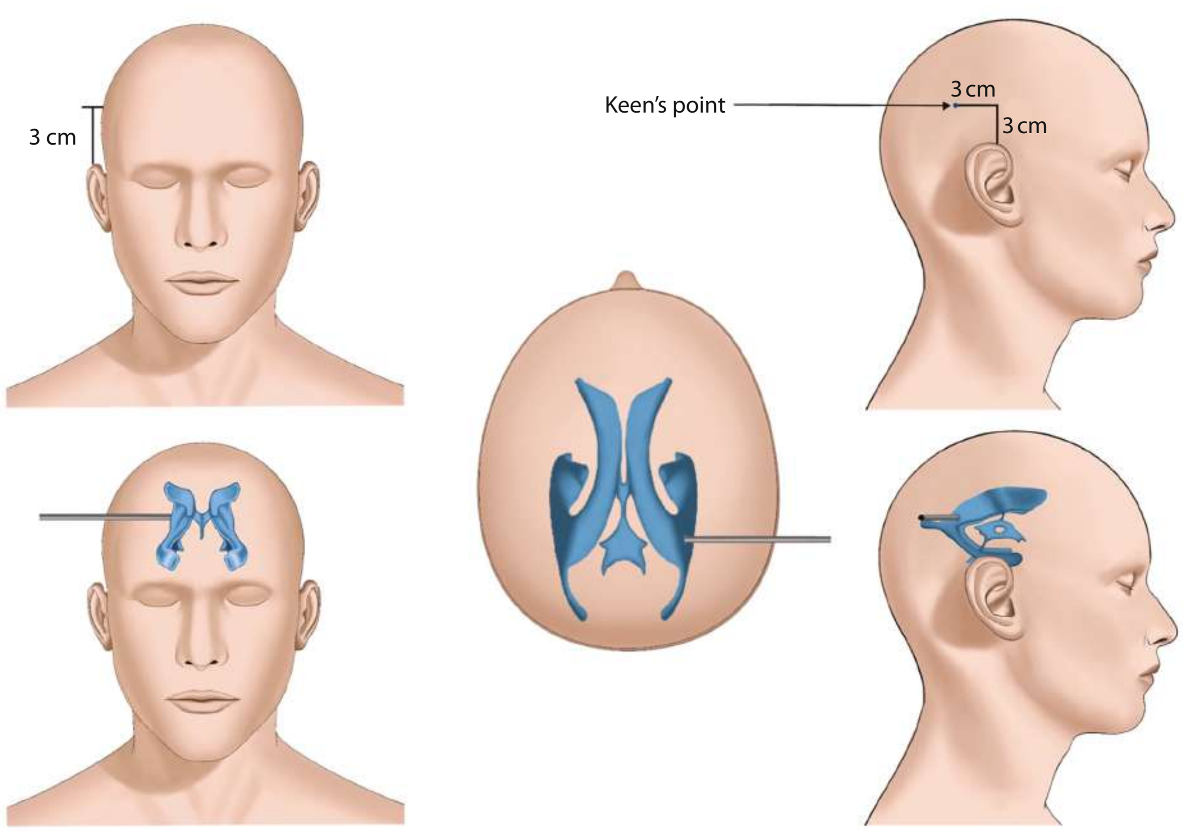
Secure informed consent after discussing the potential benefits and risks. Administer broad-spectrum intravenous antibiotics as prophylaxis. Apply local anaesthesia to the scalp at the planned insertion site, which can be supplemented with sedation or general anaesthesia based on the patient's condition and the urgency of the situation. Place the patient supine with the head turned 60–80° away from the side of the intended catheter entry. Stabilise the head with a headrest or rolled towels.

Keen's point

Among various entry sites, the one located in the posterior parietal region known as Keen's point is usually the easiest to get into the ventricle. Keen's point is situated 3–4 cm above the tip of the pinna and 3–4 cm posterior to this point. This site provides a direct, and often a short, trajectory to the lateral ventricle, usually allowing easier entry (Figure 24.14).

Sterilisation and draping

Thoroughly clean the area with an antiseptic solution and drape the patient to create a sterile field, leaving only the operative site exposed.



24.14 Schematic diagram of the placement of an EVD: tapping of the right lateral ventricle via Keen's point and a burr hole. (Image by Mr Derrick Pradeep C from Grayscalart.) ⏎

Burr hole creation

Make a 3 cm incision at Keen's point down to the level of the skull. Use a perforator drill or a Hudson brace to create a burr hole at the incision site. Remove any bone fragments and gently cut the dura to expose the underlying brain. Coagulate the dural edges and pia mater with low-power bipolar coagulation kept at 25 W (see Figures 24.5 and 24.5A).

Tap the ventricle

Using a brain needle, tap into the ventricle. The direction should be orthogonal to the surface of the brain. Insert gently and watch out for a 'give away' or a loss of resistance sensation, which indicates an entry into the ventricle. Withdraw the stylet to see the reflux of CSF that may spurt under high pressure. This confirms entry into the ventricle. Remove the brain needle. A tract to the lateral ventricle has now been created.

Catheter insertion

Use curved mosquito forceps, tunnel their tip via the same incision and bring them out of the scalp at another site 4–5 cm away (inside-out). Open the tip and use the forceps to tunnel in the tip of a No 7 or 8 French size infant feeding tube. Tunnelling of the infant tube is complete. Clean the tip of the infant feeding tube and, using the trocar of a brain needle or any similar instrument, guide it into the ventricle via the previous tract. Remove the trocar as soon as a loss of resistance is felt again and CSF egress is visible. Advance the catheter a maximum of 6–7 cm from the surface of the brain and check the backflow of CSF.

Catheter securing

Once CSF flow is confirmed, connect the distal end of the infant tube to a drainage bag. Secure the catheter with sutures ensuring the system is kept at the appropriate height to prevent over-drainage (usually at the height corresponding to the tragus).

Wound closure

Close the incision with sutures or staples and dress the site appropriately.

POSTOPERATIVE CARE

After EVD placement, monitor the CSF drainage closely, adjusting the height of the drainage system to maintain CSF flow to about 8–10 mL/hour.

Regularly assess the patient's neurological status, watching for any signs of infection or changes in ICP. Additional CT scans may be warranted to evaluate the resolution of hydrocephalus.

PEARLS OF WISDOM

- Make sure that the direction of the brain end needle is perpendicular to the burr hole surface and not angled.
- The depth of the brain needle should never be more than 5.0 cm on any given attempt.
- Ensure that the catheter and the drainage system are free of air to prevent the risk of pneumocephalus.
- Keep the drainage system closed until it is ready to be connected to the catheter to maintain sterility.
- Regularly check and document the volume and characteristics of the drained CSF.
- Be cautious of rapid decompression of the ventricles, which can lead to complications such as subdural haematomas or upwards herniation. A reasonable rate is 8–10 mL/hour.
- Maintain a low threshold for a diagnosis of meningitis.

TAPPING OF A CEREBRAL ABSCESS

INTRODUCTION

An intracranial abscess is a life-threatening condition that requires immediate medical intervention. Emergency tapping, or drainage, is indicated when a patient presents with signs of raised ICP, impending herniation or a neurological deficit that correlates with the abscess location. It is also urgent when the abscess size is causing mass effect or when it fails to respond to antibiotic therapy alone.

CT DIAGNOSIS

CT imaging with contrast is the diagnostic standard for an intracranial abscess, which typically appears as a ring-enhancing lesion with surrounding oedema. The central area is hypodense, representing pus, surrounded by a capsule that enhances with contrast administration. CT helps in localising the abscess and determining its size, which is crucial for surgical planning (see Figure 24.13b). For localising the abscess, a radio-opaque localisation marker can be placed just above the abscess with the help of a radiologist. Avoid the midline and trajectory on large venous sinuses.

SURGICAL TECHNIQUE OF A BURR HOLE AND TAPPING OF THE ABSCESS

Anaesthesia and positioning

Administer local anaesthesia with sedation or general anaesthesia. Position the patient's head to provide optimal access to the abscess site. Cleanse the area thoroughly with antiseptic, apply sterile drapes and maintain a sterile field throughout the procedure.

Incision and burr hole

Make a skin incision over the abscess site, identified by CT. Create a burr hole through the skull with a drill, exposing the dura mater as explained in the previous section. Open the dura with a cruciate incision with a 15-blade scalpel to expose the brain matter.

Aspiration

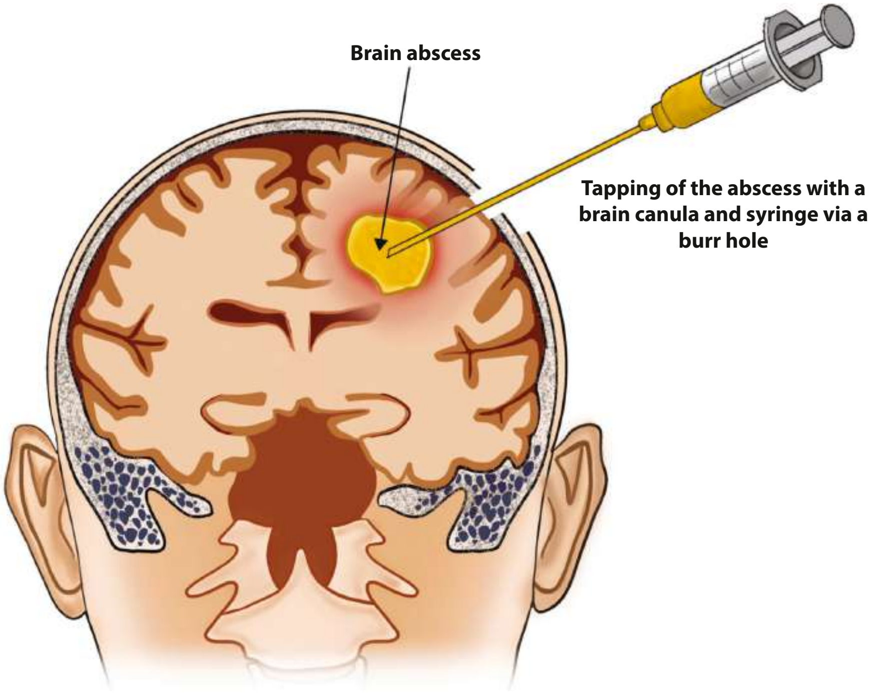
Coagulate the surface of the brain matter under low-power 15 W. Insert a sterile needle or catheter into the abscess cavity, being mindful of the depth, and gently aspirate the pus. Minimise manipulation to avoid spreading the infection (Figure 24.15).

Closure

Place a drain to allow continued drainage of the abscess, if indicated. Close the skin incision, leaving the drain in place if used.

POSTOPERATIVE CARE

Monitor the patient for signs of infection and neurological changes, and ensure proper management of the drainage system. Administer antibiotics as per microbial sensitivity and provide supportive care, including analgesia and monitoring of vital signs. Schedule follow-up imaging to assess for abscess resolution.


Brain abscess
Tapping of the abscess with a brain canula and syringe via a burr hole

24.15 Schematic diagram of tapping of a cerebral abscess via a burr hole. (Image by Mr Derrick Pradeep C from Grayscalart.) ⏎

PEARLS OF WISDOM

- Adequate preoperative and postoperative antibiotics are crucial.
- Localise the abscess accurately. Choose the shortest path to the abscess. Calculate the maximal allowable depth to avoid double puncture of the wall.
- Coagulate surface blood vessels over the brain using low-power bipolar coagulation and illumination.
- Monitor for seizures, which are a common complication post-abscess drainage.
- Early involvement of infectious disease specialists can guide antibiotic therapy.
- Stop aspiration immediately if bleeding occurs.

SPINAL TRAUMA: EMERGENCY LAMINECTOMY

INTRODUCTION

Emergency spinal decompression through laminectomy is indicated when there is evidence of acute spinal cord compression presenting with progressive neurological deficits, such as paraparesis or cauda equina syndrome. Conditions leading to such urgent decompression include traumatic fractures, an epidural haematoma or abscess, and acute disc herniation with neurological impairment. The goal is to relieve pressure on the spinal cord or nerve roots to preserve neurological function and prevent permanent damage.

DIAGNOSIS

Diagnosis begins with plain X-rays to assess for spinal alignment, fractures or dislocations. CT scans provide detailed images of bony structures and can identify fractures not seen on X-rays. Magnetic resonance imaging (MRI) is the gold standard for visualising soft tissue pathology including herniated discs, ligamentous injury and spinal cord compression. It provides the most reliable assessment of the degree, and location/level(s), of the compression and is essential for surgical planning. In an emergency without access to MRI, CT myelography can be an alternative to delineate compression when MRI is contraindicated or unavailable.

STEPS OF EMERGENCY SPINAL DECOMPRESSION LAMINECTOMY

Patient preparation and anaesthesia

Adequate anaesthesia is critical. In a resource-limited setting, spinal or general anaesthesia can be administered. Position the patient prone on bolsters or pillows that allow the abdomen to hang freely to decrease venous pressure to minimise epidural bleeding.

Incision and exposure

Perform a posterior midline incision over the affected levels, identified preoperatively using imaging. Palpate the spinous process to localise the desired levels. The length of the incision depends on the number of vertebrae involved.

Muscular dissection

Subperiosteal dissection of the paraspinal muscles is performed to expose the spinous process and the laminae. A monopolar cautery is invaluable in this scenario. Retractors are placed to maintain exposure. Dissect the muscles until the spinous process, laminae and medial aspect of the facet joints are exposed.

Laminectomy

Identify the correct spinal level using intraoperative imaging if available. Perform the laminectomy using a combination of Kerrison rongeurs and high-speed drills to remove the laminae, taking care not to breach the dura or the facetal joint or damage the underlying neural tissue (Figure 24.16).

Decompression

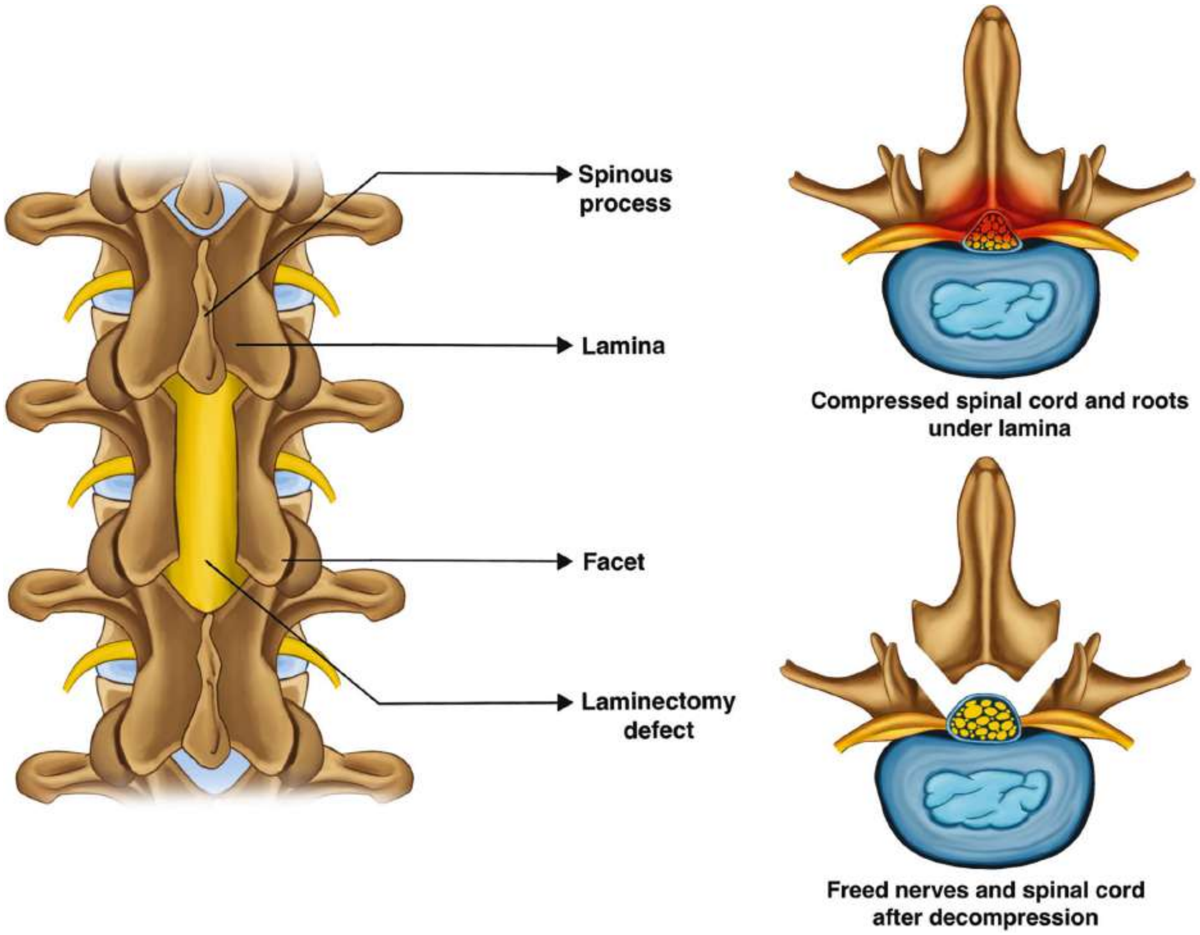
Under direct vision, carefully remove any compressive elements such as bone fragments, disc material or blood clots. Ensure that decompression of the neural elements is adequate (see Figure 24.16).

Closure

Irrigate the surgical site thoroughly and strive for meticulous haemostasis. Close the wound in layers, ensuring that the muscle and fascia are re-approximated over the decompressed area.

POSTOPERATIVE CARE

Postoperative care involves close monitoring of neurological status, pain management and the prevention of complications such as infection or CSF leak. Management includes antibiotics, steroids if indicated


Spinous process
Lamina
Facet
Laminectomy defect
Compressed spinal cord and roots under lamina
Freed nerves and spinal cord after decompression

24.16 Schematic diagram showing the exposure and bony removal required to perform a decompressive laminectomy. (Image by Mr Derrick Pradeep C from Grayscalart.) ⏎

and physical therapy to encourage early mobilisation while avoiding stress on the surgical site.

PEARLS OF WISDOM

- Familiarise yourself with the spinal anatomy before the procedure.
- Keep blood loss to a minimum by careful dissection and haemostasis.
- Continuously check for a CSF leak, which may require a repair if the dura is breached.
- Avoid excessive retraction on the spinal cord or nerve roots.

CLOSURE OF AN OPEN MYELOMENINGOCELE

INTRODUCTION

An open myelomeningocele is a form of spina bifida in which there is a congenital defect of the spine and spinal cord, with the spinal contents exposed through an opening in the back. Emergency closure is required to prevent infection, protect the exposed neural tissues from additional trauma and minimise the risk of further neurological deficit. This procedure is typically performed within the first 24–48 hours of life to decrease the risk of meningitis or other complications.

DIAGNOSIS

Diagnosis is often made prenatally via ultrasound. After birth, the defect is apparent on physical examination. X-ray, CT or MRI can be utilised postnatally to assess the extent of the defect, the presence of hydrocephalus and other anomalies. MRI provides the most detailed imaging of the spinal cord and associated structures, but, in an emergency setting, the diagnosis is predominantly clinical.

STEPS OF EMERGENCY CLOSURE

Positioning

Place the neonate prone, ensuring that there is no pressure on the defect.

Sterilisation and draping

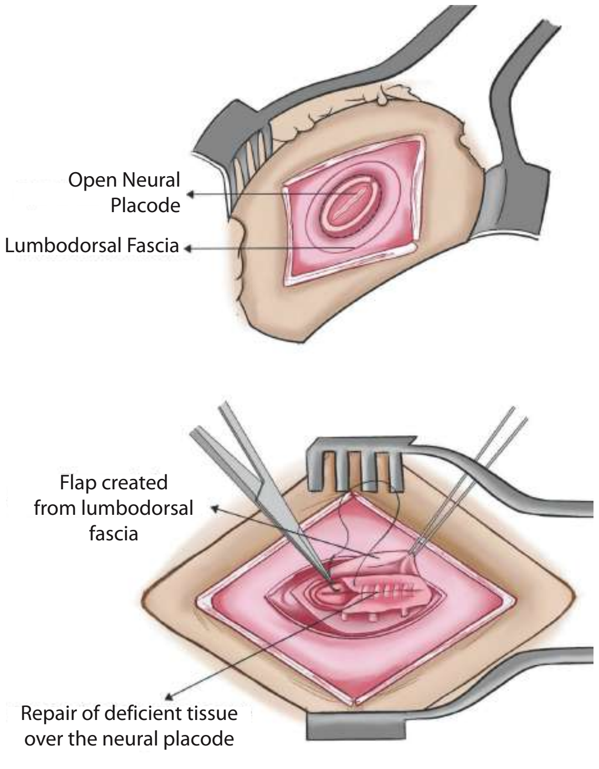
Prepare the surgical site with antiseptic solutions, and drape to maintain a sterile field. Do not use alcohol-containing solutions on the neural structures.

Surgical technique

Make a midline incision to circumscribe the myelomeningocele sac. Dissect carefully to preserve the neural placode and surrounding skin for closure. If the sac has ruptured, perform meticulous debridement (Figure 24.17). Identify and place the neural placode back into the spinal canal gently. This can be identified by locating dorsal nerve roots running laterally in the canal. Close the dura over the neural elements with fine, non-absorbable sutures. Repair the defect in the muscles and fascia. Mobilise adjacent skin to achieve tension-free closure. Close the skin using non-absorbable sutures in a watertight manner. If primary skin closure is not possible, consider rotational flaps or skin grafting.

POSTOPERATIVE CARE

Postoperatively, monitor the neonate in a neonatal intensive care unit setting. Assess for signs of infection or CSF leak and maintain the integrity of the closure. Commence prophylactic antibiotics. Perform serial head circumference measurements and neurological checks to monitor for hydrocephalus. Consult with paediatric neurosurgical experts for further management, including the potential need for ventriculoperitoneal shunting if hydrocephalus develops.


Open Neural Placode
Lumbodorsal Fascia
Flap created from lumbodorsal fascia
Repair of deficient tissue over the neural placode

24.17 Schematic diagram demonstrating the closure of an open myelomeningocele in a neonate. (Image by Mr Derrick Pradeep C from Grayscalart.) ⏎

PEARLS OF WISDOM

- Handle tissues with the utmost care to avoid further damage to the exposed neural elements.
- Maintaining a sterile field is paramount to prevent infection.
- Anticipate the need for further neurosurgical intervention.
- Early multidisciplinary involvement, including neonatology and paediatric neurosurgery, is crucial for the comprehensive care of the child.

CONCLUSION

In rural and resource-limited settings, general surgeons are often the first and only line of defence in neurosurgical emergencies. These moments demand not just courage but a shift in surgical philosophy.

Understanding that brain and spinal tissues do not forgive trauma or time lapse, and that visual clarity is as vital as the scalpel, allows surgeons to adapt their practice safely. Mastery over simple yet critical practices – gentle suction, irrigation, cautious bipolar use and atraumatic clot evacuation – can preserve life and function even in austere environments.

Moreover, stabilising the patient with optimal blood pressure, oxygenation and ICP control can dramatically improve outcomes. And, while immediate surgical intervention may be necessary, the ideal outcome always includes timely referral and coordination with neurosurgical services when possible.

This chapter aims not to make a neurosurgeon out of a generalist, but to equip the general surgeon with the essential principles and practical approaches needed in emergencies. With preparedness, presence of mind and precision, surgeons can provide effective initial care and be a critical bridge between crisis and specialised treatment, ultimately saving lives when time and geography conspire against the patient.

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25 Urological surgery for the general surgeon

Partho Mukherjee and Anthony Devasia

Urology as a surgical speciality has been functioning independently for several decades. However, in many parts of the world, due to various circumstances, general surgeons are required to carry out urological procedures both electively and occasionally in the emergency setting. Some of the common urological procedures are included in this chapter. A more detailed reference and the assistance of a urologist is preferable for more complex procedures.

GENERAL PRINCIPLES

Renal function

It is imperative to perform adequate imaging (e.g. an intravenous urogram [IVU] or contrast-enhanced computed tomography [CT] scan) to check the position and function of the kidneys, prior to any elective surgery on the kidney or ureter. If this information is not available, especially in the emergency situation, an on-table IVU with a single shot film, taken at 20 minutes, provides the maximum information.

Renal vascularity

The kidneys receive one-fifth of the total cardiac output, and haemorrhage from the renal parenchyma can be profuse. Vascular control of the renal vessels is essential, and the anterior approach provides quick access to the renal pedicle, especially in trauma situations. During vascular occlusion, renal tissue is damaged by ischaemia faster than any other tissue, except the brain.

Pelvicalyceal system

Hydronephrosis refers to dilatation of the pelvis and calyces of the kidney. It may be congenital, secondary to a muscular incoordination resulting in a functional obstruction, or due to a mechanical obstruction from intra-mural, mural or extra-mural causes. Dilatation can also occur without any evidence of obstruction and is frequently bilateral and associated with hydroureters. This is seen in pregnancy and in ureteric reflux. The differentiation between a dilated and an obstructed collecting system is essential, as the former often requires no intervention. However, the stagnant urine is susceptible to infection. An obstructed system requires drainage, or correction of the underlying pathology, as the increased pressure in the calyces results in deterioration of renal function that eventually becomes irreversible. The urgency of the situation depends on the severity of the obstruction, whether one or both kidneys are obstructed, and whether there is infection. Bilateral obstruction or obstruction in a solitary kidney is of greater urgency, and an obstructed infected kidney is an emergency that should be addressed immediately. Acute unilateral obstruction without infection should also be dealt with on a priority basis. Bladder outlet obstruction may result in increasing post-void residue that is prone to infection, stone formation and eventually urinary retention.

Methods of drainage depend on the site of obstruction. The kidney is drained effectively to the exterior by a nephrostomy placed percutaneously or by open surgery. Internal drainage of the kidney into the bladder can be carried out by a double J stent. The bladder is drained by a urethral catheter or suprapubic drainage.

Advanced pelvic malignancies may cause unilateral/bilateral ureteric obstruction. Often, the diagnosis of inoperable or recurrent cervical, uterine, prostatic, bladder or rectal cancer is already established, but the patient presents with anuria. Nephrostomy drainage, or the placement of ureteric stents, from either above or below across the malignant stricture will prolong life. However, this decision must be made very carefully, in the light of the suffering from advanced pelvic malignancy.

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Patients who present with ureteric obstruction before a definitive diagnosis has been reached pose combined challenges of diagnosis and initial management. Malignancy should be confirmed histologically, and benign retroperitoneal fibrosis cannot be excluded. Some malignancies are amenable to curative treatment, even at this stage, and respond to radiotherapy, chemotherapy or hormone manipulation, with the potential for regression and long-term survival. Initial nephrostomy or ureteric stents will be required to stabilise the patient for tissue diagnosis and for appropriate management to be planned. Normal renal function is essential for the tolerance of many chemotherapeutic agents.

STONE FORMATION

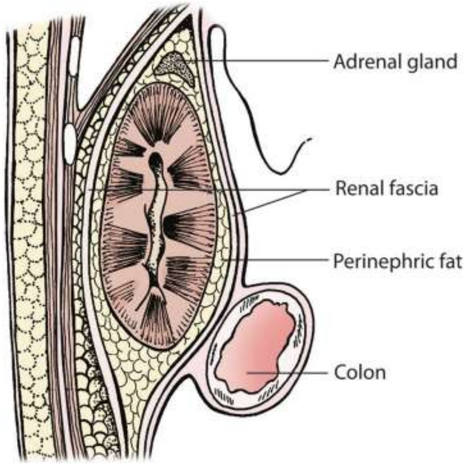
Any foreign body in contact with urine can stimulate stone formation; consequently, all sutures should be absorbable. Stents and catheters will eventually encrust, although the materials from which long-term catheters and stents are fashioned are designed to reduce this. If long-term stents are needed, the stents are usually removed and replaced by novel stents at 4- to 6-monthly intervals. A high fluid intake, with resultant dilute urine, also reduces encrustation, but the stents need to be changed at regular intervals.

SURGICAL ANATOMY

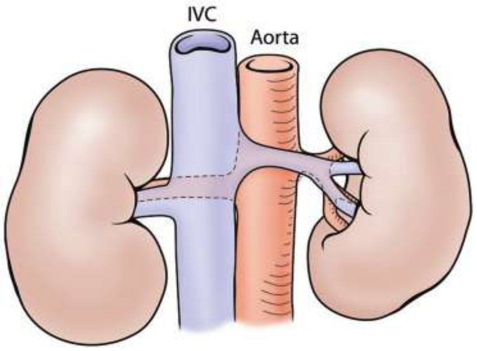
THE KIDNEYS

The kidney is enveloped in a *fibrous capsule* and consists of the parenchyma and the collecting system. The glomeruli are within the outer parenchyma or *cortex*. The collecting tubules in the inner parenchyma, or *medulla*, open on the papillae into the *calyces* of the collecting system. The calyces unite to form the *renal pelvis*. The collecting system lies partially enclosed within the renal parenchyma, but part of the renal pelvis lies extrarenal before it tapers to the *pelvi-ureteric junction*. The *renal fascia* (Gerota's fascia) encloses the kidney, the adrenal gland and the perinephric fat (Figure 25.1).

The *renal pedicle* consists of the renal vein (which lies anterior), the renal pelvis and ureter (which is posterior), and the renal artery (which lies between the two). The right renal vein is short, as the right kidney lies very close to the inferior vena cava (IVC) (Figure 25.2). Anatomical variants are not uncommon. These include multiple hilar vessels (artery or vein), partial or complete duplex systems, horse-shoe kidneys, ectopic and crossed fused kidneys.



25.1 A sagittal section of a kidney showing its relationships to perinephric fat, adrenal gland, renal fascia, pleura and colon. ⏎



25.2 The standard vascular anatomy of the renal pedicle. The right renal vein is short. The longer left renal vein crosses anterior to the aorta. The renal arteries, which may be multiple, are behind the veins. ⏎

The duodenum and hepatic flexure lie anterior to the right kidney: the splenic flexure, pancreatic tail and spleen are closely applied to the left kidney. The kidneys lie retroperitoneally and may be approached, at open or laparoscopic surgery, from the abdomen or from the loin. An open abdominal approach is transperitoneal and the loin approach is retroperitoneal. Laparoscopic renal surgery can also be performed using either approach, but is more commonly performed transperitoneally.

THE URETERS

The ureters commence at the pelvi-ureteric junctions and run distally in the retroperitoneum to end at the ureteric orifices in the bladder. The intravesical segment runs an oblique course through the bladder wall musculature, and this acts as a valve during bladder filling and micturition, preventing ureteric reflux.

The ureteric wall is muscular, and visible contractions (or *vermiculations*) enable the surgeon to identify the ureters at laparotomy.

In terms of *X-ray position*, on an IVU, the course of the ureter extends from the renal pelvis down the tips of the transverse processes of the lumbar vertebrae, over the sacroiliac joints, laterally towards the ischial spines and then medially to the bladder.

During intra-abdominal surgery, the ureter must be identified early in any operation that may place it at risk of injury. Mobilisation of the caecum or pelvic colon commences with incision of the peritoneum lateral to the bowel, which is then swung medially. Dissection proceeds with great care and the ureter is identified. It lies behind the gonadal vessels on the psoas muscle and generally crosses the pelvic brim at the bifurcation of the common iliac vessels. It is also at risk in aortoiliac vascular surgery. In the pelvis, the ureter is at greatest risk as it turns medially towards the trigone of the bladder.

In women, the ureter crosses deep to the uterine arteries at the base of the broad ligament, a phenomenon known as 'water under the bridge', and may be inadvertently included in the ligation of the uterine arteries during hysterectomy.

In any difficult pelvic dissection, the ureters can be identified above the pelvic brim and followed on their anterior surface into the pelvis and towards the bladder. A tunnel is created by gently inserting a pair of artery forceps distally along the anterior surface of the ureter from the portion that is already displayed.

THE BLADDER AND PROSTATE

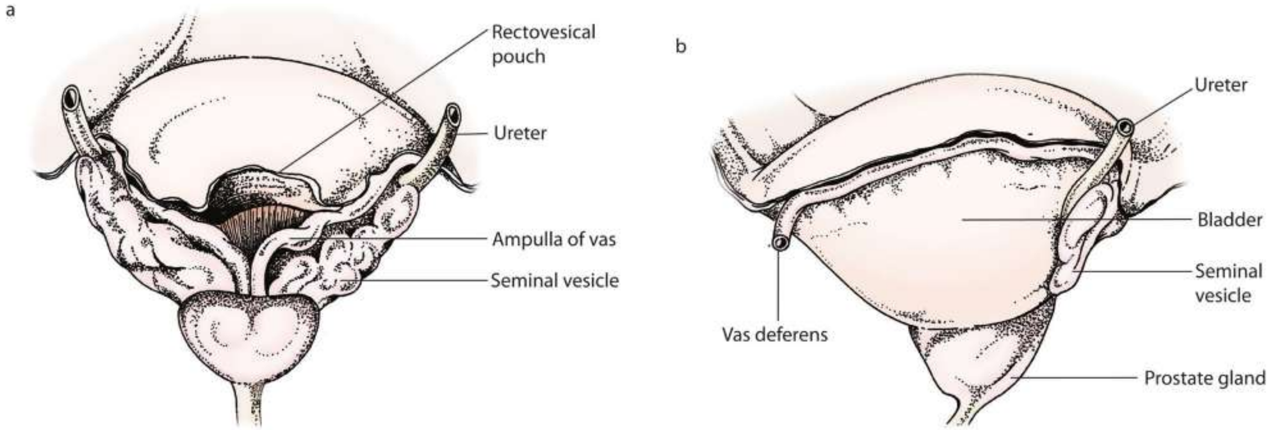
The bladder lies behind the pubis and is mainly extraperitoneal, lying below the peritoneal reflection. In men, it is separated inferiorly from the pelvic floor musculature by the prostate gland and posteriorly it is separated from the rectum by the seminal vesicles and Denonvilliers' fascia (Figure 25.3). In women, the bladder lies directly on the pelvic floor and is separated posteriorly from the rectum by the vagina. The ureters enter the bladder posterolaterally within a centimetre or two of the internal urethral opening.

KIDNEY

Currently, in many well-equipped centres, most procedures on the kidney are performed laparoscopically or are robotically assisted, and renal calculi are dealt with endoscopically. There are several procedures that a general surgeon may be required to perform on the kidney. In the elective setting, renal surgery may be for a benign condition or a malignancy involving the kidney. As an emergency, renal surgery is invariably for trauma, where the abdomen is often already open. Planning an open approach on a kidney depends on various key factors such as the underlying pathology, the size of the lesion and the involvement of surrounding structures, by either infiltration or inflammation. It is imperative to study the preoperative imaging carefully and note the number of hilar vessels and involvement of adjacent organs. In patients with renal tumours, involvement of the renal vein by a thrombus should be looked for. If the IVC is involved in a renal tumour, it is recommended that the patient be referred to a specialised centre. Well-planned surgical access allows the surgeon to operate on the kidney safely and efficiently.

Listed below are the approaches recommended by the authors for certain conditions:

- Flank approach (extraperitoneal) – Indications:
  - Benign
    - Hydronephrosis, contracted small kidneys
    - Infection and inflammatory
    - Infected hydronephrosis
    - Xanthogranulomatous pyelonephritis
    - Emphysematous pyelonephritis
    - Renal calculi



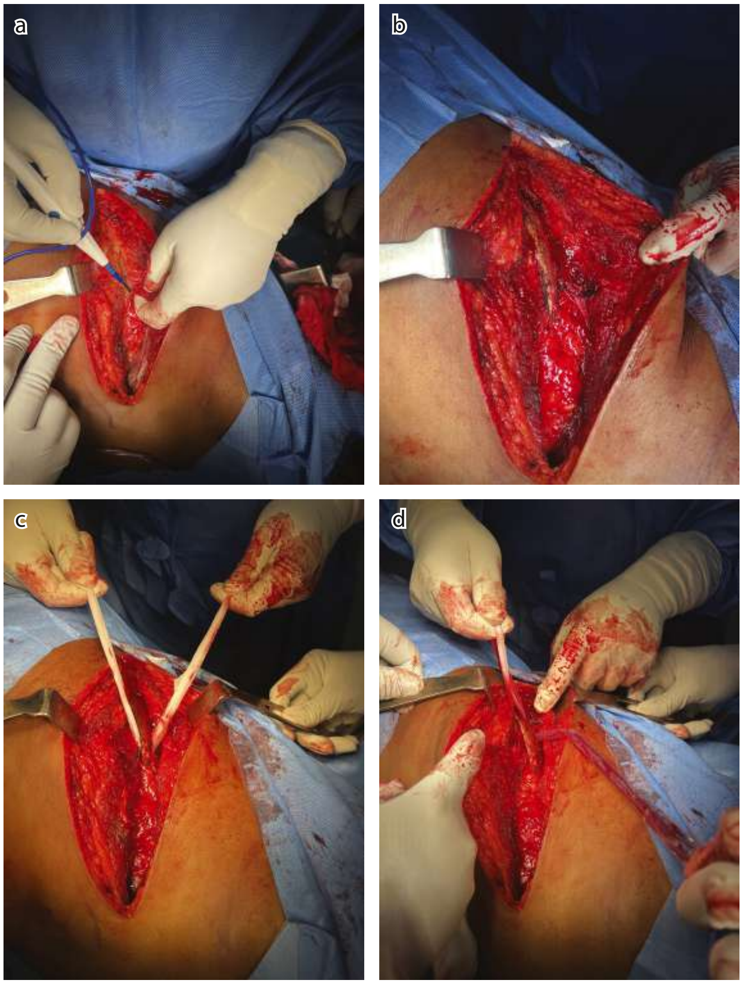
25.3 (a) The posterior view of the bladder in men. (b) A lateral view of the bladder. ⏎

- Malignant
    - Small renal tumours
    - Radical or partial nephrectomy
- Anterior approach (intraperitoneal)
  - Benign
    - Large polycystic kidneys
  - Malignant
    - Large renal tumours

NEPHRECTOMY

Flank approach

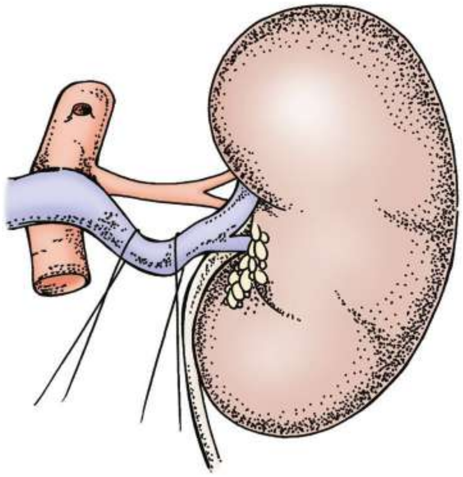
The flank incision may be subcostal, along the 12th rib, between the 11th and 12th rib or along the 11th rib. The patient is positioned and strapped in the lateral position with the back close to the edge of the table. The flank (between the costal margin and the iliac crest) is opened up by flexing the table, keeping the point of break of the table in line with the iliac crest in the lateral position. The straps are placed across the greater trochanter and the chest, taking care to avoid interference with ventilation. A subcostal incision is adequate for most benign conditions. For other conditions, it is prudent to palpate and mark the patient's 11th and 12th ribs. Incision is deepened in layers down to the lumbodorsal fascia. The fascia is opened and the preperitoneal space is developed towards the midline by blunt dissection up to the anterior abdominal muscles medially. If a rib-cutting incision is used, the tissue right at the tip of the rib (lumbodorsal fascia) is incised and a finger is used to feel and free up the preperitoneal space. The tip of the rib is then held over the finger of the surgeon, or an Allis clamp, and cautery is used to incise sharply on the periosteum of the rib until bare bone is seen. The periosteum is shaved away from the rib until most of the circumference of the rib is exposed (Figure 25.4a, b) up to and beyond the posterior axillary line, if required. Once the periosteum has been lifted off the rib, a rolled wet gauze placed below the rib can be used to push away the underlying periosteum, along with the pleura (Figure 25.4c, d). The rib is excised with a rib cutter, avoiding injury to the pleura. If the dissection is directed perpendicularly downwards, it allows the



25.4 (a, b) Taking the periosteum off the rib. (c, d) Pushing away the underlying peritoneum and pleura. ⏎

pleura to move away. Despite the utmost care, there may be injury to the pleura while separating the periosteum or cutting the rib. Damage to the pleura should be addressed immediately, using absorbable sutures under positive pressure ventilation, making sure the lung is well expanded. If the pleura is very thin, or the sutures cut through, the pleura may need mobilisation, separating the attachments to the diaphragm to reduce tension, along with buttressing of the edges with the surrounding intercostal muscle or fat. If the defect is large with collapse of the lung, an infant feeding tube may be placed with an underwater seal. To ensure full lung expansion, the tube is withdrawn while inflating the lungs, before closing the last part of the defect. Further separation of the pleural attachments and the peripheral diaphragmatic fibres to the ribs helps the pleura to be retracted further. This step prevents further tearing or traction of the pleura when the retractors are placed.

If a simple or partial nephrectomy is planned, the renal fascia is identified posterolaterally, incised and retracted. In a radical nephrectomy for malignancy, the self-retaining retractors are positioned after complete pleural and peritoneal mobilisation. The dissection stays superficial to the Gerota's fascia. The peritoneum anterior to the renal fascia is separated until the ipsilateral ureter and the gonadal vein are identified inferiorly. These two structures are important landmarks. In a left-sided nephrectomy, the left gonadal vein and the ureter are followed cephalad up to the hilum in the avascular plane. Care must be taken not to avulse the left gonadal vein off its origin from the renal vein. The right gonadal vein drains into the IVC and is dissected medially off the ureter. Occasionally, accessory arteries or veins run laterally towards the ureter, or the lower pole of the kidney, and require division. The divided ureter on the specimen side gives a good structure to allow traction to reach the hilum of the kidney. On dissecting the kidney off the psoas posteriorly, the renal arterial pulsations can be felt on the tip of the finger medially. The upper pole is released and separated from the adrenal gland and the renal vein is dissected free. The artery is identified posteriorly (Figure 25.5) and double ligated and divided. The vein should be tied only if it is collapsed to avoid bleeding, in case a second artery has been missed. The renal vein is looped proximal to the adrenal vein, close to the kidney on the left side, taking care to avoid avulsing a lumbar vein. In the case of a suspected thrombus extending into the renal vein, even up to the ostium, the thrombus may shrink after ligating the artery, making it possible to ligate and divide the vein beyond the thrombus with a sufficient venous stump. On the right side, the peritoneum is mobilised medially to display the IVC and the short right renal vein. After ligating the renal artery, the renal vein is dissected free. A Satinsky clamp can be placed on the IVC and, after division, the IVC wall is sutured with continuous 4/0 Prolene. The specimen is removed, and the renal fossa and hilum are checked for bleeding. The incised flank and lateral abdominal muscles are closed in two layers with absorbable sutures, avoiding the pleura. A drain may be placed in the case of anticipated ooze from the fossa but is rarely required.



25.5 The left renal vein has been retracted to expose the renal artery. The vein can be retracted cranially or caudally. Ligation of the artery before the vein prevents renal engorgement. ⏎

Anterior approach

Large renal masses, which may be crossing the midline, or a large polycystic kidney are best approached transperitoneally, anteriorly, via a subcostal or a Chevron incision.

The patient is positioned supine with the hands by the side, with a small soft bolster placed under the ipsilateral upper back. It is safer to strap the patient to the table if the table needs to be rotated. The Chevron incision is made about two finger breadths below the costal margin. The incision is deepened in layers and the external oblique fascia is incised along with the anterior rectus sheath. The rectus is divided and the peritoneum is entered. The muscle layer is divided along the skin incision, up to the anterior axillary line. The incision can be extended up to the contralateral rectus muscle if the exposure is not adequate. The falciform ligament is divided. Excision of the xiphisternum may be needed for better exposure of the liver and the suprahepatic vena cava if an IVC thrombectomy is planned. The lateral peritoneal attachment of the large bowel is incised and the bowel is mobilised medially, from the caecum to the hepatic flexure on the right and from the splenic flexure to the sigmoid colon on the left. It is usually possible to mobilise up to the great vessels on the left side. On the right side, the second and third part of the duodenum is dissected off the right kidney and IVC.

A self-retaining retractor is placed after mobilising the colon, with the colon and bowel retracted towards the midline to expose the renal hilum and the great vessels. The ipsilateral ureter and the gonadal vein are identified. In a left nephrectomy, the left gonadal vein and the ureter are followed cephalad up to the hilum. Care should be taken to make sure that the planes between the kidney and the pancreatic tail, the splenic vessels and the spleen are maintained. The renal artery is identified posterior to the renal vein (see Figure 25.5) but, if there is difficulty, the kidney is 'flipped' medially, allowing palpation of the renal artery, perpendicular to the great vessels.

A complex scenario arises when there is a tumour thrombus extending to the renal vein. This makes the kidney extremely vascular and also makes the posterior approach to the right renal artery risky, as handling the thrombus could cause it to dislodge and embolise. The right renal artery can be approached in the inter-aortocaval groove, where it is seen arising from the aorta just posterior to the left renal vein, medial to the aorta.

In masses crossing the midline, good exposure of the hilum and clear identification of the landmarks is extremely important. This can prevent inadvertent ligation of the contralateral renal vessels or ureter and avoid injury to the IVC, aorta, duodenum, pancreas and spleen. Occasionally, bleeding from the adrenal gland may require control with a suture.

Special scenarios in nephrectomy

There are certain conditions that change the relationship of the kidney to its surrounding structures, with often dense adhesions or infiltration to the organs around it, making nephrectomy a challenging procedure. It is of the utmost importance to be aware that a nephrectomy should not be performed in the acute stage, in the presence of pus and sepsis. The patient's condition should be stabilised by percutaneous drainage of the pus pockets or the collecting system by percutaneous nephrostomy.

Chronically infected kidney with or without a calculus (e.g. xanthogranulomatous pyelonephritis and emphysematous pyelonephritis) Xanthogranulomatous pyelonephritis is an aggressive form of chronic pyelonephritis associated with renal calculus and infection. CT images of the kidney show a 'bear paw' sign, with loss of tissue planes between the kidney and surrounding structures. In emphysematous pyelonephritis, CT images show air pockets and pus in the kidney. The acute stage involves stabilisation of the patient by percutaneous drainage of the pus and air pockets prior to nephrectomy. These conditions present a surgical challenge. A clear liquid diet for a day or more prior to the surgery is advisable. Consent should be taken for potential injury to surrounding organs, especially the colon and duodenum. An extraperitoneal flank incision is preferred. Intraoperatively, careful dissection is required along the plane deep to Gerota's fascia, staying away from the bowel and duodenum. If the colon is densely adherent to the kidney, the peritoneum is opened to identify the colon and the colon is dissected off the kidney. Occasionally, there may not be any tissue planes for dissection. The subcapsular plane can be used in this scenario to get all the way around the kidney by finger dissection. The capsule is incised close to the hilum and the extracapsular space is entered to secure the vessels. When there are pus pockets, the renal tissue is likely to be friable and may come out piecemeal. An alternative is to mass clamp the tissue at the hilum. Once the specimen is removed, every effort should be made to identify and ligate the vessels separately to avoid an arteriovenous fistula formation. If the vessels cannot be identified, the hilar stump is suture ligated en masse.

A non-functioning kidney with a stone in the pelvis, or proximal ureter, may present similar challenges in dissection.

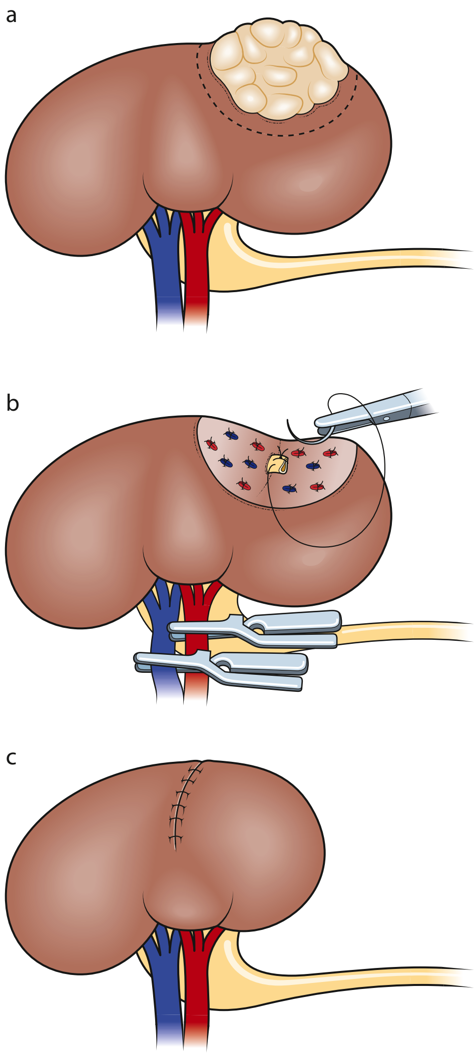
Large hydronephrotic kidney A large hydronephrotic kidney with paper thin parenchyma can often extend beyond the midline. The preferred approach is by an extraperitoneal flank incision. Care should be taken not to deflate the kidney too early. This helps in identifying the plane deep to the renal fascia, keeping the surrounding structures pushed away. It may be difficult to reach the medial aspect of the kidney, and the hilum, despite mobilisation. After initial development of the planes around the kidney, a 'controlled decompression' is carried out using a stab incision at the centre of a purse-string suture on the parenchyma. A suction cannula is inserted to partly deflate the kidney. With further dissection, it is possible to 'gather' the deflated parenchyma and reach the hilum. As the parenchyma is often paper thin, it may be mistaken for fascia. Clear demarcation of the hilum and the ipsilateral ureter can prevent inadvertent ligation of the contralateral renal vessels or ureter or injury to the duodenum or IVC. Careful haemostasis of the kidney bed is important after the specimen is removed. As there is a large raw surface, a drain may be placed in the cavity for a couple of days after the surgery.

Open partial nephrectomy

An open partial nephrectomy may be feasible when the renal neoplasm is small, completely or partly exophytic, and well circumscribed and away from the renal hilar vessels, renal sinus fat and pelvicalyceal system (PCS). More complex lesions should be referred to a urologist for a partial nephrectomy or considered for a radical nephrectomy.

The approach to the kidney is as described earlier, through an extraperitoneal flank incision. The renal fascia is opened and the perinephric fat is dissected away to expose the kidney and the complete circumference of the neoplasm. The renal vessels are looped. The visible borders of the tumour are marked on the renal capsule by cautery with a margin of a 2–3 mm of normal parenchyma (Figure 25.6a). A low mean arterial pressure of about 80 mmHg is maintained during the excision. Once the renal artery is occluded with a vascular (non-occlusive) clamp or a bulldog clamp, the kidney is covered in ice 'slush' to produce surface cooling. The kidney is kept submerged in the ice slush for at least 10–15 minutes to attain a core renal temperature of about 20°C, which allows preservation of renal parenchyma in spite of ischaemia. The ice slush is then removed. The safe ischaemia time is about 30 minutes. The marked tumour margins are then deepened with cautery, or a scalpel, and then with blunt dissection using the back end of a knife handle. Using the peri-tumour fat for traction, the tumour is mobilised from its bed in the kidney. The assistant holds and stabilises the kidney. The vessels encountered during dissection are sutured with a fine (4/0 or 5/0) *Prolene* suture in a figure-of-eight stitch (Figure 25.6b), making sure the needle strikes the parenchyma at right angles to ensure enough purchase. The tumour is excised from its bed with a thin rim of parenchyma, and the bed is inspected for any bleeding vessels. Any suspicious residual tumour fragments are excised and sent separately.

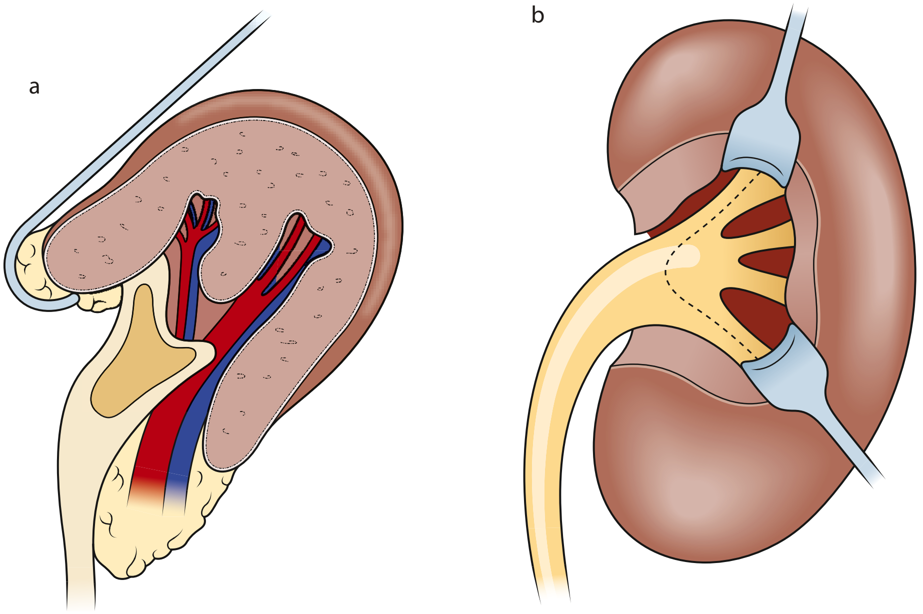
If the collecting system has been opened, fine absorbable interrupted sutures are used to close the collecting system. A ureteric catheter placed into the pelvis cystoscopically prior to the surgery allows saline or diluted methylene blue to be injected intraoperatively to check the integrity of the collecting system. After initial haemostasis is secured, the arterial clamp is released and any new bleeders that become evident are sutured. Interrupted sutures are placed along and across the edges of the defect with a thick absorbable suture. The parenchymal bites should be deep to prevent cutting through as the sutures are tightened (Figure 25.6c). A mobilised section of vascularised perinephric fat can be passed under the interrupted sutures, and the sutures tied securely, while the edges are approximated. The blood pressure is restored to the pre-induction level and the kidney is allowed to regain its perfusion fully before checking haemostasis again. The renal fascia is closed, and a drain may be left in the paranephric space for a few days postoperatively.



25.6 (a) The border of the tumour is marked with a 2–3 mm margin. (b) The vessels are occluded and cut and the collecting system is sutured. (c) Parenchymal apposition. ⏎

Heminephrectomy

A heminephrectomy is indicated when one moiety alone of a duplex kidney is severely damaged. There may be obstruction or reflux in one of the duplex ureters, with subsequent stone formation, infection, renal scarring and loss of function only in the part drained by that ureter. The associated vascular separation of the two portions of the duplex kidney makes a heminephrectomy an option to retain the functioning moiety. The hilum is dissected to identify the vessels and the ureter to the moiety that is to be removed. After ligation of these vessels, the two moieties can be separated with minimal blood loss.



25.7 Exposure of the subadventitial plane of the pelvis. (a) Extension of the incision to the calyces in the subadventitial plane. (b) Pyelolithotomy. (Adapted from Gil-Vernet.[6]) ⏎

Pyelolithotomy

The current optimal treatment of renal calculi is by endoscopic methods. However, if no suitably trained surgeon or adequate endoscopic equipment is available, open pyelolithotomy may be the only option. Care must be taken to assess the function of the kidney prior to the surgery. In a functioning kidney with a calculus, there may be chronic pyelonephritis, making planes around the kidney difficult to dissect. With an extraperitoneal approach, the renal fascia is incised to mobilise the kidney as described above. The ureter is identified and traced to the hilum to clearly visualise the pelvis. A curved incision is made on the pelvis with the convexity of the curve pointed towards the pelvi-ureteric junction (PUJ) and the calculus is removed. When the calculus extends into the calyces, the incision on the pelvis may not be sufficient to deliver the calculus from within the calyces. Using a scalpel blade, a fine transverse incision is made on the adventitia of the exposed pelvis to enter the avascular subadventitial plane (Figure 25.7a). Using a wet pledget, this avascular plane is developed all the way deep on to the calyx to be accessed for extended pyelolithotomy. The incision can be extended into the calyces to access the calculus (Figure 25.7b). Fluoroscopic guidance is required to ensure removal of all fragments. Small fragments can be flushed out with saline. Once the stones are cleared, a double J stent is passed antegrade into the ureter and the proximal loop is placed in the pelvis. The incisions on the pelvis and the calyces are closed with a 4/0 absorbable suture. Continuous sutures can be used to approximate the edges. Interrupted sutures may be required if the edges are under tension. A drain is placed in the retroperitoneum. The urinary system is kept well drained with a urethral catheter. This can be removed 48–72 hours after confirming the position of the stent and stone clearance on a kidney, ureter and bladder X-ray. If the drain output increases after removal of the catheter, indicating a minor leak, the catheter is reinserted for a further period.

Haemorrhage from the renal pedicle

Haemorrhage from the renal pedicle can occur when a clamp or ligature slips or a vessel is injured during dissection. Profuse bleeding can obscure all structures. Blind attempts at catching the bleeding vessel should be avoided. Instead, gauze packs are pressed into the wound and the haemorrhage is controlled by digital pressure. The anaesthetist should be appraised of the situation to maintain adequate venous access, and blood should be obtained for transfusion. If possible, extra assistance should be sought. If the haemorrhage is from a divided vessel, it should be possible to remove the packs after waiting at least 10 minutes to slow the bleeding in order for the severed vessel to be identified and secured. More frequently, especially on the right side, the bleeding may be from a side tear in the IVC. This bleeding will not reduce spontaneously. Digital pressure through swabs can temporarily control the situation. The pressure is then withdrawn sequentially from above until recommencement of bleeding indicates the proximal extent of the caval tear. A continuous 4/0 vascular suture is started at this point and continued distally as the digital control is sequentially withdrawn from the IVC. It is sometimes possible to apply a large Satinsky clamp on the IVC to isolate the tear while it is sutured.

Laparoscopic radical nephrectomy

The shorter length of the right renal vein, the proximity of the IVC and the presence of the duodenum makes a laparoscopic nephrectomy more difficult on the right side. The position of the patient on the table is the same as for a nephrectomy by a flank extraperitoneal approach as described earlier in the chapter. However, the anterior abdominal wall is placed close to the edge of the table. An axillary roll is placed to protect the brachial plexus. Pneumoperitoneum of 15 mmHg is established. After the camera port is placed, the abdomen is inspected for signs of port placement-related injury, adhesions and anatomical landmarks. The remaining trocars are placed to form an equilateral triangle with the camera port, with the lateral ports placed along the midclavicular line. A left nephrectomy is performed with a 5 mm port for the left hand and 10 mm ports for the right hand and camera port. The right nephrectomy may need all three 10 mm ports and an extra 5 mm port at the epigastrium to retract the liver. The peritoneal reflection of the colon is incised to reflect the bowel medially, exposing the renal fascia. On the right side, the colon is mobilised from the hepatic flexure down to the lower pole of the kidney. The division of the coronary ligaments of the liver allows retraction of the liver. The ureter and the gonadal vein are identified lateral to the IVC at the lower pole of the kidney. The duodenum is Kocherised to expose the anterior aspect and the right lateral border of the IVC. The right ureter is dissected off laterally from the gonadal vein. With the ureter under traction applied by an instrument in the left hand placed under the ureter, the tissue between the IVC and the ureter is dissected cranially until the right renal vein is identified and dissected free. The right renal artery is approached posterior to the renal vein. However, if the artery is placed cranially, it can be approached anteriorly at the cranial border of the renal vein.

On the left side, the colon is mobilised from the splenic flexure up to the lower pole of the left kidney. The splenorenal and the splenophrenic ligaments are also incised to mobilise the spleen. A well-mobilised spleen, assisted by gravity with the patient in the lateral position, drops away from the operative field, together with the splenic flexure and the descending colon. The gonadal vein can be either divided between clips or preserved and retracted laterally with the ureter. These structures are then followed cranially up to the left renal vein. The left gonadal vein, left adrenal veins and the lumbar veins need careful dissection to prevent avulsion. The lumbar vein may require ligation to access the renal artery. It is safer to cut the renal end of the lumbar vein with a small stump of vein to be able to place another clip or grasper in the case of a bleed. The main renal artery and vein are clipped and divided with scissors. The renal fascia is released circumferentially and the adrenal gland is dissected off the upper pole of the kidney. An adrenal tear may require a running suture. The ureter is divided and the kidney is extracted through a Pfannenstiel incision. The renal fossa and the hilum are inspected before removing the ports. The 10 mm ports are closed with a suture.

Nephro-ureterectomy

A nephro-ureterectomy is the excision of a kidney with its ureter. The indications include (1) a non-functioning kidney with a distal ureteric stricture or calculus or primary obstructive megaureter and (2) transitional cell carcinoma (TCC) of the renal pelvis and ureter. In ureteric TCC, complete excision of the entire ureter with a cuff of bladder is imperative for oncological control. The mobilisation of the proximal ureter along with the kidney is similar to a nephrectomy. This part of the procedure can be done open via an extraperitoneal flank incision or laparoscopically transperitoneally along with the renal fascia. As kidneys with ureteric TCC often have hydronephrosis, care must be taken not to rupture and cause spillage. There may be an intense desmoplastic reaction, especially after chemotherapy.

If the tumour is located in the upper ureter and renal pelvis, early ligation of the ureter distal to the lesion is advised. After the radical nephrectomy part is completed, the dissection of the ureter is carried further down into the pelvis as far as possible dividing the ipsilateral gonadal vessel. Further medial mobilisation of the ipsilateral large bowel is required to expose the ureter. The kidney is then dropped down into the pelvis and the lower ureter is accessed through a separate incision.

If the patient was in the lateral position initially, the flank wound is closed completely and the patient is re-draped in the supine position with a small bolster behind the ipsilateral gluteus. Either a Pfannenstiel incision, extended more to the ipsilateral side, or a modified Gibson incision is used. This incision is deepened in layers up to the transversalis fascia, which is incised. The peritoneum is reflected medially to expose the iliac vessels. If a laparoscopic nephrectomy is carried out, the opening created in the peritoneum is used to deliver the specimen. If the kidney is bulky, the ureter can be divided and the rest of the dissection continued with traction on the ureteric stump. To gain access to the distal most part of the ureter, the ipsilateral superior vesical pedicle is divided. Adequate retraction is required to clearly visualise the ureterovesical junction. A one finger breadth margin cuff of bladder is taken around the ureteric orifice by placing stay sutures. An initial anterior incision on the bladder allows the early identification of the contralateral orifice. The opening is extended around the ureter and the specimen is removed. The bladder is closed with absorbable sutures leaving a pelvic drain. The urethral catheter is kept in place for 7–10 days. Haemostasis is secured and abdominal muscle layers are closed.

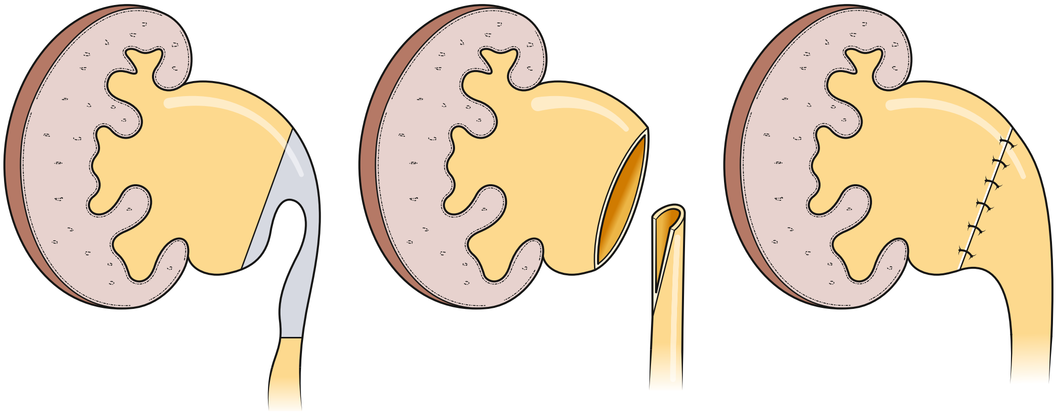
NEPHROSTOMY

This is an emergency treatment for patients with sepsis secondary to an obstructed kidney drainage system, and the collecting system is drained to the outside. Ultrasound-guided percutaneous nephrostomy drainage is usually the first choice in management in an infected hydronephrosis. If ultrasound is not available, an attempt can be made to drain the kidney endoscopically from below by guiding a catheter up the ureter, past the obstruction, under image intensifier control, but if this is not possible, an open nephrostomy through a loin approach may be the only option.

Pyeloplasty

Congenital PUJ obstruction is secondary to a muscular incoordination at the PUJ and results in hydronephrosis. Surgical correction by pyeloplasty is indicated for obstruction rather than a simple dilatation, and careful preoperative assessment is essential with a drainage study and preferably an isotope renogram. The PUJ is divided and reconstructed to form a wider junction with more dependent drainage without tension (Figure 25.8). The operation can be performed laparoscopically in the lateral position. For an open operation, the patient is placed in a semilateral position and a subcostal incision is made to expose the PUJ retroperitoneally on its anterior aspect. A marker suture is placed at the most dependent part of the pelvis and the narrow segment is excised until a normal-calibre ureter is reached. The ureter is spatulated laterally and anastomosed to the renal pelvis. If there is an abnormal lower pole vessel, the reconstruction is carried out anterior to the vessel. Occasionally, there may be a long stenotic segment and, after excision, the cut end of the dependent part of the pelvis may not reach the ureter. Complete mobilisation of the kidney up to the pedicle will allow the pelvis to be brought closer to the ureter to facilitate the anastomosis. This manoeuvre can also be used in redo pyeloplasty where intense fibrosis in, and around, the previous anastomosis may create a long defect after excising unhealthy tissue.

Unless the pelvis is very large and redundant, it is not necessary to excise much pelvic tissue. Absorbable sutures are used to reconstruct the junction to avoid the risk of stone formation. The bladder is distended by clamping the urethral catheter, and a ureteric stent or an infant feeding tube is passed over a guide wire into the bladder. The following simple technique can be used to confirm that the lower curl of a double J stent is in the bladder. The tip of a 5 Fr infant feeding tube is slit like a fish mouth and checked to see if a 0.32 guide wire can easily be passed through.



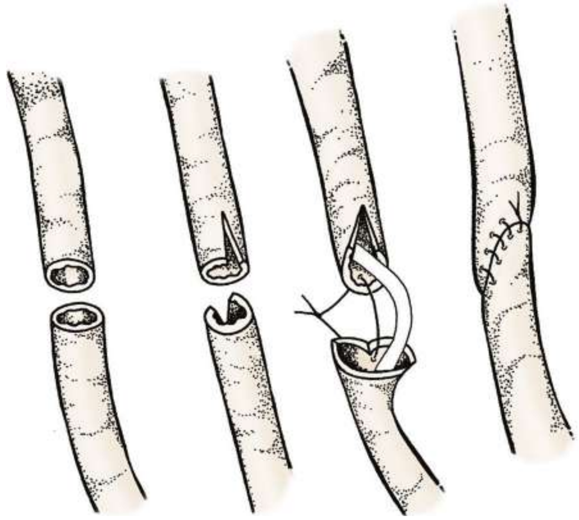
25.8 Dismembered pyeloplasty. The stenotic segment is excised and reconstructed to provide dependent drainage. ⏎

The feeding tube is passed down into the bladder and urine is aspirated to confirm that the tip is in the bladder. A sufficient length of the guide wire is then passed through the feeding tube to emerge through the fish-mouthed tip and the feeding tube is removed. The stent can now be passed over the guide wire into the bladder. Pelvicalyceal dilation may persist at follow-up imaging but requires no further intervention.

The laparoscopic approach has become the standard of care; however, it should only be performed by a surgeon trained in intracorporeal suturing.

RENAL TRANSPLANTS

A patient with a renal transplant may present to the general surgeon with other unrelated intra-abdominal pathology. The allograft kidney is usually placed retroperitoneally in the right iliac fossa. Care has to be taken during dissection of the caecum for a right-sided transplant and of the sigmoid colon in a patient with a left iliac fossa transplant.



25.9 An end-to-end anastomotic repair of a divided ureter. Each end of the ureter is spatulated. This results in a wide, oblique anastomosis, which is carried out with interrupted sutures over a ureteric stent. ⏎

URETER

URETERIC DAMAGE

Ureteric trauma is usually iatrogenic and most commonly occurs in general or gynaecological surgery. In some instances, ureteric resection is intentional, for example when a ureter is invaded by an otherwise resectable primary tumour. In other patients, inadvertent damage can occur. The ureter may be ligated in error and, unless the injury is bilateral or in a solitary kidney, the surgeon may remain unaware of the problem. This may result in permanent damage to the kidney. A difficult dissection close to the ureter can cause ischaemic damage with late stricture formation and ureteric obstruction. Damage to a ureter can also be caused by injudicious use of diathermy that may not be apparent at the time of surgery. When ureteric damage is recognised, the surgeon should, if possible, seek assistance. In accidental injury to the ureter, the choice of procedure for that particular patient has to be considered carefully, based on knowledge and understanding the implications. It is therefore important that help is sought from a urological colleague if at all possible.

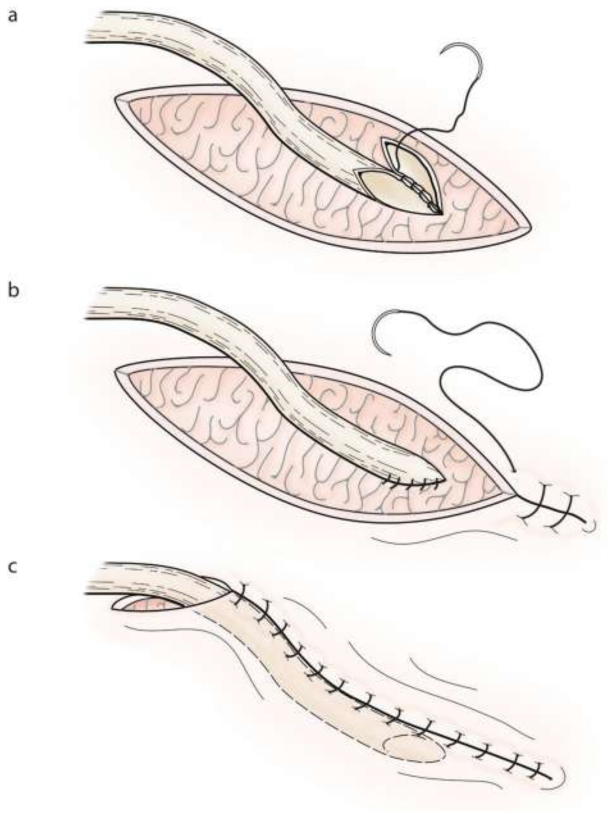
SIMPLE REPAIR

Simple repair with interrupted fine absorbable sutures is only possible when there is minimal loss of tissue (Figure 25.9). The vascularity is checked and the edges are freshened and spatulated to reduce the chance of an anastomotic stricture. An infant feeding tube/ureteric double J stent is inserted over a guide wire. The infant feeding tube has to be anchored to the ureter with an absorbable suture. A drain is left in the retroperitoneal space. Following the removal of the stent/splint after 3–4 weeks, a contrast study such as an IVU or a CT is carried out to assess drainage from the kidney and exclude a stricture at the level of the repair.

REIMPLANTATION INTO THE BLADDER

Reimplantation into the bladder is a reconstructive option that should be considered when simple repair is not possible. It is particularly suitable when the ureteric division is close to the bladder. The bladder is opened and the divided ureter is spatulated to produce a wide anastomosis to prevent stenosis. An oblique tunnel is created through the bladder wall and the anastomosis is performed over a ureteric stent. Mucosal apposition is achieved using fine absorbable sutures, and the bladder muscle wall is closed around the ureter with sutures that also tether the muscular coat of the ureter to the bladder (Figure 25.10).

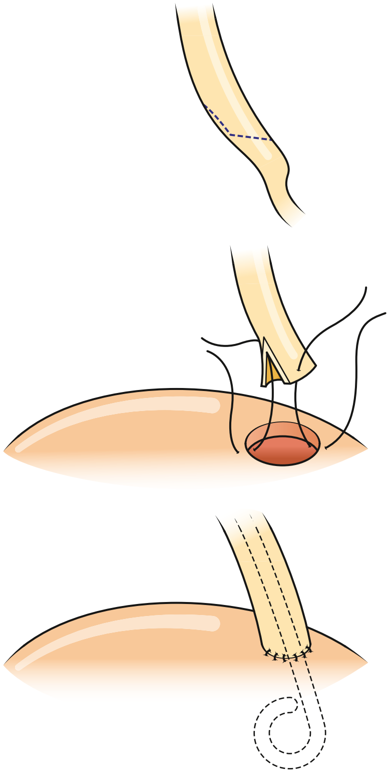
Any tension on the anastomosis must be avoided. Stenosis is one of the most dreaded complications and should be kept in mind during the anastomosis, as it commonly originates from tension compromising vascularity. A full-thickness anastomosis between the spatulated ureter and the bladder with a double J



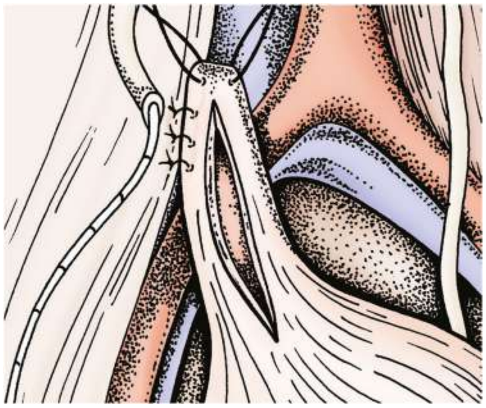
25.10 Direct reimplantation of a ureter into the bladder is occasionally possible after a distal injury if there is sufficient length. The creation of an intramural tunnel will prevent reflux. (a) A 2–3 cm incision is made through the muscle coat of the bladder. At one end, the incision is deepened through the mucosa. This mucosal incision should create an aperture of similar diameter to that of the spatulated ureter. An anastomosis is performed. (b) The muscle layer of the bladder wall is closed over the ureter. (c) The ureter is lying in an intramural tunnel. The final suture of the muscle layer can also be used to pick up the outer layers of the ureter to reduce traction on the anastomosis. ⏎

stent can also be carried out (Figure 25.11). A psoas hitch, where the bladder is hitched up and fixed to the psoas muscle, prior to the reimplantation is a useful manoeuvre to reduce tension (Figure 25.12). Mobilising the bladder on the contralateral side will facilitate reimplantation. When there is more loss of ureteric length, a flap of bladder (Boari flap) can be raised and formed into a tubular extension to the bladder (Figure 25.13). Division of the contralateral superior vesical pedicle will allow further mobilisation of the bladder.

An isolated ileal loop, fashioned to form a ureteric replacement, is another option when there is a long segment of proximal ureter to be replaced. However, this requires very careful consideration in a young patient, in view of the lifelong consequence of passage of ileal mucus in the urine.

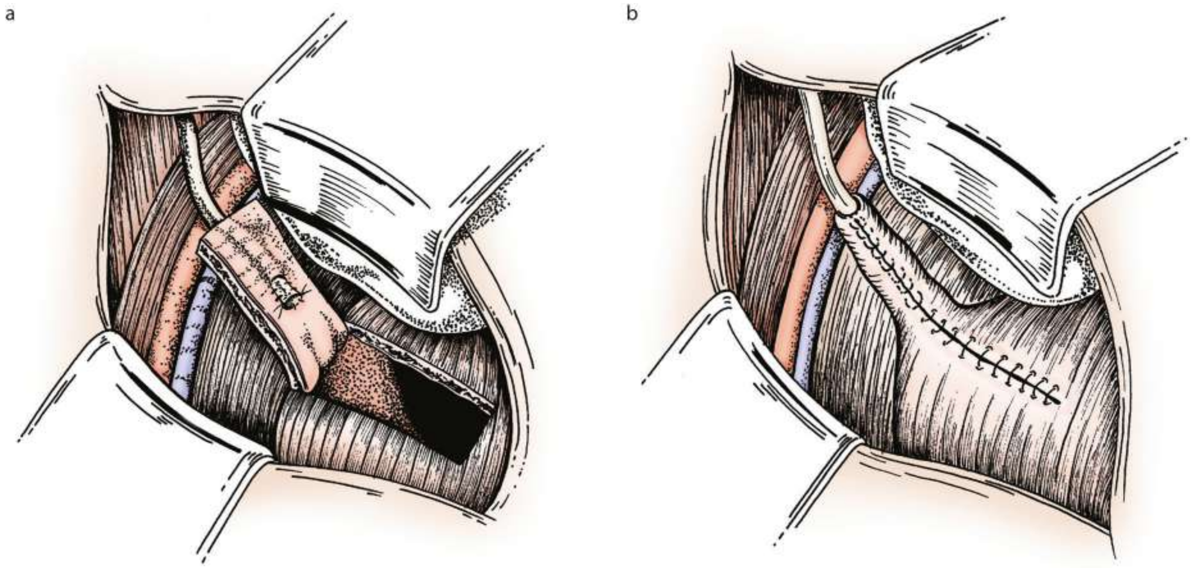


25.11 A direct ureter-to-bladder full-thickness anastomosis without a tunnel. ⏎



25.12 A psoas hitch. The bladder is drawn up, out of the pelvis, and fixed to the psoas muscle. This shortens the distance over which the ureter has to reach and reduces anastomotic tension. ⏎

Reimplantation of a ureter into the bladder may also be needed for a distal ureteric obstruction (e.g. stricture, primary obstructive congenital megaureter) or at renal transplantation.



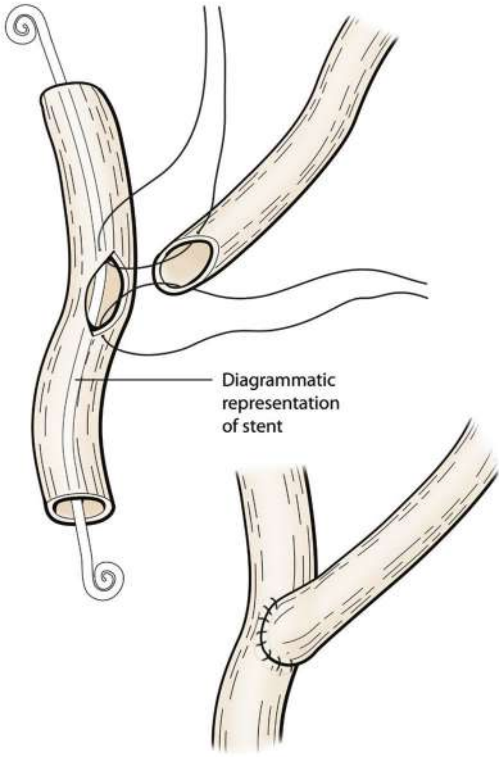
25.13 A Boari flap. (a) The bladder must be drawn over to the side of the injury; increased mobility will be obtained by mobilising the opposite side of the bladder. A long flap, with a superolateral base, has been cut from the bladder. The ureter is anastomosed to the flap, with a submucosal tunnel. (b) The flap is tubularised and the suture line is continued to close the donor defect. ⏎

URETERO-URETEROSTOMY

Reimplantation of a divided ureter into the contralateral ureter can be considered in any situation in which direct repair is not possible. A diseased ureter, or the ureter of a very poorly functioning kidney, should never be implanted into a healthy ureter. The proximal portion of the ureter is dissected and freed so that it can be drawn across the midline. The contralateral ureter will also need mobilisation to achieve a tension-free anastomosis. Ureters should be mobilised carefully, retaining the ureteric sheath, to prevent ischaemia. The divided end is spatulated and anastomosed end-to-side into the other ureter, both of which should be stented (Figure 25.14).

URETERIC STONE REMOVAL

Ureteric calculi often cause colic and partial obstruction when the stone is passing spontaneously. Stones less than 6 mm in diameter are likely to pass spontaneously, and a short trial of conservative management for a few weeks by treatment with an alpha-blocker such as tamsulosin or alfuzosin may be appropriate. An impacted calculus and the presence of infection are contraindications for medical expulsive therapy. Removal of a ureteric calculus is an elective procedure once it becomes apparent that the stone will not pass spontaneously. If obstruction is only intermittent, or partial, a delay of some weeks may not be detrimental to renal function.



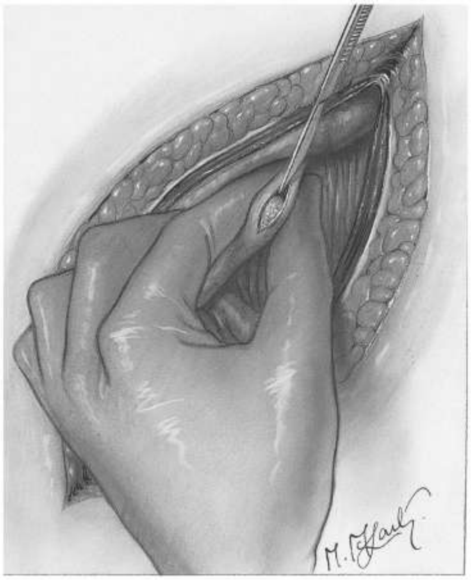
25.14 Implantation of a divided ureter into the other ureter is frequently the most satisfactory solution when a ureter has been damaged and length has been lost. ⏎

Current treatment of a ureteric calculus, in urological practice, is almost always by endoscopic techniques or by lithotripsy. However, a general surgeon practising in a remote area may still need to remove a ureteric stone at open surgery.

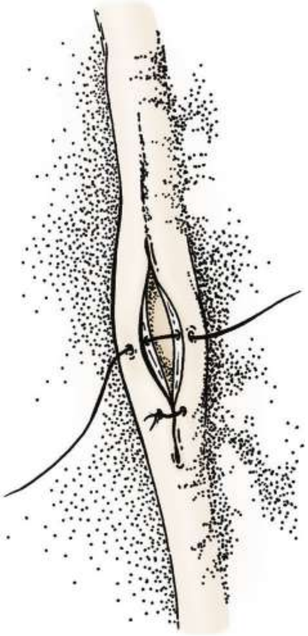
OPEN URETEROLITHOTOMY

A plain kidney, ureter and bladder X-ray should be taken on the day of the surgery to check for the presence and position of the calculus. The site of the incision will depend on the position, and the ureter is approached retroperitoneally. During the exposure, the ureter can get retracted anteriorly along with the peritoneum. If there is any difficulty, it may be easier to identify the ureter initially at the pelvic brim.

The calculus is recognised by a fusiform swelling of the ureter and confirmed by palpation. A tape is passed around the ureter above the calculus to prevent its upwards displacement into the dilated system. A second tape is passed around the ureter below the calculus. Two stay sutures are placed on the ureter at the level of the stone and a longitudinal incision is made between the stay sutures, directly over the calculus. The incision begins over the widest part of the stone and extends upwards to a level just above its upper end (Figure 25.15) and the calculus is delivered. An infant feeding tube is passed up and down to wash out any debris. An infant feeding tube or a double J stent is inserted over a guide wire into the bladder. The incision on the ureter is repaired with fine absorbable sutures (Figure 25.16). When the ureteric wall is traumatised and oedematous, sutures may cut through and the incision can be left open. A drain is left in the retroperitoneum, as urine leakage may occur for a few days. The urethral catheter is removed only after the leakage has stopped. The ureteric stent can be removed a few weeks later. If intraoperatively the calculus is palpated at the ureterovesical junction, and cannot be disimpacted, a cystotomy can be carried out and the ureteric orifice incised to extract the calculus.



25.15 Ureterolithotomy (an original drawing by Margaret McLarty for the first edition of this book published in 1954). ⏎



25.16 Closure of a longitudinal incision into a ureter has the potential to cause a stricture. Sutures should be loose and well spaced and ideally should exclude the mucosa. ⏎

BLADDER

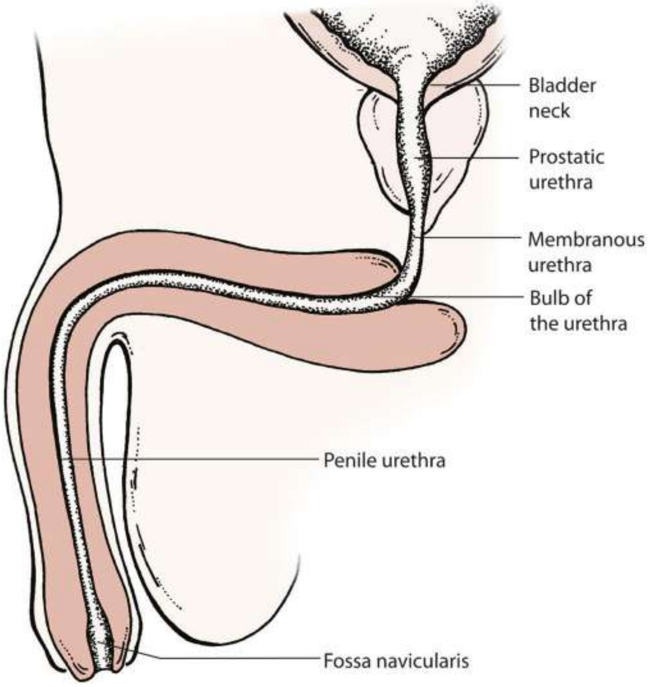
CATHETERISATION

Urethral catheterisation

Urethral catheterisation is required for many procedures in the perioperative and early postoperative period. Often, the catheter is inserted after induction of anaesthesia. On some occasions, the catheter has to be inserted postoperatively for urinary retention. As with all invasive urological procedures, antibiotic cover is advisable. A small Foley-type catheter (size 12–14) with a 5–10 mL self-retaining balloon is satisfactory.

Difficulties in female patients are usually related to situations in which the urethral meatus has been drawn up on to the anterior vaginal wall or into a stenosed vagina. The position of the urethral meatus is identified digitally in the midline at the junction between the smooth vulval and the corrugated vaginal mucosa, and the catheter is guided in on the index finger.

Difficulties in male patients are often related to inadequate lubrication and a lack of appreciation of the curves of the male urethra (Figure 25.17). About



25.17 A sagittal section of the male urethra. The change in direction between the bulbar and the membranous urethra has to be kept in mind during any intubation. ⏎

10 mL of lubricant local anaesthetic jelly is introduced with a syringe into the urethra to ensure adequate lubrication. In an anxious patient, sedation may be required. The balloon should be inflated only after urine drains freely. Beware of applying too much force, as false passages can be created. If there is difficulty, further trauma to the urethra should be avoided and a suprapubic catheter should be inserted, provided the bladder is full and palpable, or the urethra visualised with a cystoscope. A failed urethral catheterisation at the start of an abdominal operation can wait for a suprapubic catheter to be inserted once the abdomen is open and the bladder has filled.

PERCUTANEOUS SUPRAPUBIC CYSTOSTOMY

Percutaneous suprapubic catheterisation is a method to drain a distended bladder when urethral catheterisation is not possible. A full bladder is a prerequisite. To distend the bladder quickly, a spinal needle or a long 16–18 G intravenous cannula is advanced in the midline just above the pubic symphysis, urine is aspirated and saline infusion is started with the cannula in place. Another method is to insert a fine (5–8 Fr) infant feeding tube into the urethra until free passage is possible to fill the bladder from below. Local anaesthetic is injected into the midline skin and abdominal wall 5 cm above the pubis. Aspiration of urine is confirmatory. A 5–10 mm skin incision is made and the linea alba is incised to reduce the force required to pierce the abdominal wall. A right-handed person stands on the left of the patient with the trocar in their right hand, directing the trocar towards the pelvis. The trocar is gripped in the dominant hand with the head of the trocar opposed against the thenar eminence, surrounded by the thumb like a corkscrew, with the index finger extended along the long axis of the trocar to act as a stop for the trocar. The suprapubic catheter is placed two finger breaths above the pubic symphysis. However, for traumatic urethral distraction defects, a suprapubic catheter is placed higher up, at a third of the distance to the umbilicus from the pubic symphysis. This helps in visualising the bladder neck and posterior urethra during repair of the urethral distraction defect. The trocar is withdrawn and the catheter is inserted down the cannula into the bladder. The bulb is inflated, the cannula is removed and the skin is sutured. The proprietary suprapubic catheterisation set has a splitable cannula that separates into two portions, facilitating removal once the catheter is in place.

SUPRAPUBIC CYSTOSTOMY

An open suprapubic cystostomy is a safe way of diverting urine from a distended bladder if facilities for a percutaneous suprapubic catheter are not available or when there is an impalpable shrunken bladder that will not distend. Bladder diversion during a laparotomy for bladder injury repair, partial cystectomy and post-major pelvic surgery are some of the common indications. The catheter is placed in the bladder by an open dissection. The preperitoneal space is entered through a suprapubic incision, the bladder is identified and a small incision is made through the bladder wall and the catheter is advanced and the balloon inflated. The bladder is closed around the catheter.

Open cystolithotomy

An open cystolithotomy is an option for removal of large or multiple bladder calculi, especially when appropriate endoscopic equipment is not available. This may be combined with a transvesical prostatectomy, if bladder stones are associated with a benign enlargement of the prostate. Prior to the procedure, a urethral stricture is ruled out by passage of a urethral catheter into the bladder and the bladder is distended. An extraperitoneal approach using a Pfannenstiel or midline suprapubic incision is used. The bladder is identified and a space is created anteriorly with blunt dissection. If there has been prior surgical procedures in the pelvis, the bladder is separated carefully from the scar tissue. The peritoneal fold over the bladder is dissected off cranially. Aspiration of clear urine is confirmatory. A full-thickness cystotomy is made longitudinally in the midline of the bladder after insertion of stay sutures. The catheter bulb, along with the bladder calculi, will be palpable inside and may be clearly seen when the bladder is opened. The calculi are then delivered without injuring the bladder mucosa. A gentle wash removes the small fragments. The bladder mucosa may be inflamed and may bleed with minimal handling. Following complete stone retrieval, the bladder is closed with interrupted full-thickness absorbable sutures. A drain is placed in the perivesical space through a separate stab incision. The wound is closed in layers. The urethral catheter is retained for at least 10 days and the drain may be removed after 48–72 hours if drainage is minimal.

The bladder and prostate are usually approached through a suprapubic incision and the dissection is in the preperitoneal plane. However, a general surgeon is more likely to be involved in surgery for the bladder from within the peritoneal cavity when the bladder is damaged by trauma or is infiltrated from adjacent bowel.

TRAUMA

Bladder trauma may result in intraperitoneal or extraperitoneal rupture. Intraperitoneal rupture occurs in blunt trauma to the abdomen with a distended bladder. A fluoroscopic or CT cystography is diagnostic. Instillation of 50 mL of contrast in 450 mL of saline into the bladder through a Foley catheter under radiological screening shows the extravasation of contrast between the bowel loops and in the paracolic gutter. Laparotomy and closure of the bladder wall with absorbable sutures is required, and a catheter must be left *in situ* for at least 10 days. Many advocate radiological assessment of the bladder prior to catheter removal. A cystogram can be performed by contrast injection via the catheter.

Extraperitoneal rupture is usually associated with major pelvic trauma, and suprapubic urinary drainage is more appropriate. Iatrogenic trauma also occurs and is most often in the form of an inadvertent entry into the bladder when opening the abdomen or during pelvic dissection. The opening is closed with absorbable sutures and the bladder is drained with a urethral catheter.

CYSTECTOMY

PARTIAL CYSTECTOMY

Partial cystectomy is feasible when the bladder is infiltrated focally by malignancy of an adjacent organ such as a sigmoid or urachal carcinoma limited to the dome of the bladder. This may also be needed for management of a colovesical fistula, usually caused by diverticular disease or a colorectal cancer. A disc of bladder may be excised, which is adherent to, and possibly invaded by, a sigmoid colon cancer. A diverticular mass may also be densely adherent to the bladder. At the time of surgery, malignancy may still be suspected and a disc of bladder should be resected *en bloc* to avoid opening potential tumour planes and compromising a curative resection. Both sigmoid colon malignancy and diverticular disease may be associated with a colovesical fistula. The concern is the proximity of the involved bladder to the trigone and the ureteric orifices. A preoperative cystoscopy will often demonstrate the area of tethered or inflamed mucosa. If the disease is close to the trigone, or difficulty is anticipated, ureteric catheterisation helps in the identification of the ureters during the dissection. After excision of a disc of bladder, the bladder wall is closed in two layers of absorbable sutures and a urethral catheter is left for at least 10 days. The more distal rectovesical fistulae, which are associated with locally invasive rectal cancer, will commonly involve the bladder trigone and a partial cystectomy is no longer an option. A pelvic exenteration and urinary diversion may be required, and these patients often need a colostomy and a urinary diversion.

RADICAL CYSTECTOMY (MEN)

The patient is positioned in a low lithotomy position with Allen stirrups. A right-handed surgeon operating from the left side of the patient can reach the depth of the pelvis more easily with the dominant right hand, the opposite being true for a left-handed surgeon. The lower thorax, the abdomen, the genitalia and the upper thighs are painted and draped. A 20 Fr urethral catheter is used to drain the bladder.

The midline incision extends from about 2 cm above the umbilicus to the pubic symphysis. The bladder is assessed to check operability, fixity to surrounding structures, the pelvic wall and involvement of surrounding structures. The urachal ligament is divided between strong sutures and the specimen end is kept long and can be used for traction on the bladder. The lateral peritoneal attachments of the bladder are divided sharply, lateral to the medial umbilical ligaments. The vas deferens is divided bilaterally. Exposing the superior border of the pubic symphysis allows better retraction of the lower ends of the rectus abdomini muscles and improves vision in the depths of the pelvis. The retropubic space is developed. A self-retaining retractor is used and the intestines packed away cranially. The large bowel on either side is mobilised and the root of the mesentery is dissected off the retroperitoneum, if required, to allow cranial retraction of the bowel. The ureters are identified bilaterally and dissected free keeping the peri-ureteric tissue intact. Judicious use of the cautery is advised to prevent thermal injury to the ureter. With the division of the superior vesical pedicle, and the obliterated umbilical artery, the ureters are exposed up to their insertion into the bladder.

The ureters are clamped and divided bilaterally as close to the bladder as possible after placing marking sutures anteriorly. Strong sutures are used to secure the ureters on the specimen side and are kept long for traction on the specimen during the dissection posterior to the bladder. The proximal ureter is ligated by a ligature and kept in place until fashioning of the anastomosis to allow distension of the ureter, which facilitates anastomosis, and to keep the operative field dry. The cut ureters are placed cranially under the retractor in the retroperitoneal space until needed later in the surgery.

With traction on the bladder, the peritoneum posterior to the bladder, between the bladder and rectum, is incised sharply, entering the space between the rectum and bladder, prostate and seminal vesicles. Following the vas deferens guides the surgeon to the plane posterior to the seminal vesicles. In the absence of infiltrative disease posteriorly, this plane is usually amenable to blunt dissection with the index finger, once Denonvilliers' fascia is divided. All the pedicles leading into the bladder from the lateral pelvic wall are then ligated and divided. It is possible to bluntly dissect beyond the prostate and feel the urethral catheter in the midline beyond. The endopelvic fascia covering the pelvic diaphragm muscles is identified anterior, and lateral, to the prostate and sharply incised on either side from the 2 o'clock to the 4 o'clock and from the 8 o'clock to the 10 o'clock position. This incision is deepened bluntly to expose the lateral aspect of the prostate gland. The puboprostatic ligament is sharply incised at the inferior border of the pubic symphysis. A pair of long Babcock forceps may be used to 'gather' the dorsal venous complex in the midline. A figure-of-eight suture with 1/0 polyglactin is taken on the dorsal venous complex and hitched on to the posterior periosteum of the pubic symphysis before division. This is best taken with the surgeon holding the needle in the dominant hand, such that the curve of the needle is parallel to the table, with the convex edge of the needle caudally, and while the surgeon's body is turned towards the patient's face. Posterior traction to the prostate is required at this time. Multiple sutures may be required, and good suction should be available as brisk bleeding may continue even after placement of the first suture. The urethra beyond the prostate is divided in the midline until the urethral catheter is exposed. The urethral catheter is clamped and divided and delivered into the wound to give traction with the balloon still inflated. The posterior circumference of the urethra and lateral attachments of the prostate are divided and the specimen is removed. Residual bleeding is controlled with absorbable sutures.

RADICAL CYSTECTOMY (WOMEN)

The initial part of the dissection is similar to that in men. The lateral peritoneal attachments of the bladder are sharply divided lateral to the medial umbilical ligaments, together with the round ligaments. The lateral uterine attachments are also ligated and divided. The ureter is identified and divided. Further dissection proceeds with traction on the bladder and uterus using Allis clamps. A wet swab on a stick is placed in the vagina, pushing the vaginal fornix cranially, and the peritoneum posterior to the bladder over the pouch of Douglas is sharply incised. Following division of the vascular pedicles on either side of the bladder, the dissection is continued to the endopelvic fascia on either side of the bladder. The infundibulo-pelvic ligament is divided. The swab on a stick placed in the vagina helps in identifying the apex of the vagina, which is incised distal to the cervix. The anterior vaginal wall is dissected off the bladder at the level of the bladder neck/proximal urethra circumferentially. The vagina is closed with 2/0, or stronger, absorbable running sutures, ensuring haemostasis. The pubo-urethral suspensory ligaments are divided to expose the dorsal vein complex, which is divided after ligation with 2/0 absorbable sutures, and the urethra is dissected off. The vaginal part of the urethra is approached from the perineum, with a vaginal speculum to achieve exposure. A circumferential peri-meatal incision is made and the urethra is dissected with blunt and sharp dissection cranially with traction on the urethral catheter. Care should be taken to avoid perforating the bladder. This is continued until the specimen is completely free and is delivered into the pelvis.

Lymph node dissection

Once the bladder is removed, the iliac vessels are fully exposed. The fibro-areolar sheath around the external iliac vessels is opened and the nodes and fibro-fatty tissue is dissected circumferentially by blunt and sharp dissection with care to ligate the proximal and distal ends of the lymphatic trunks. The limits of dissection are the genitofemoral nerve laterally, the ureter medially, the common iliac artery bifurcation cranially, the inguinal ligament caudally, and the obturator nerve posteriorly. The nodal packets are sent for histopathological evaluation, systematically noting the represented nodal stations on either side. Meticulous haemo- and lymphostasis should be achieved with surgical clips, sutures and electrocautery.

A drain is left in the pelvis and removed when deemed fit by the surgeon.

URINARY DIVERSION

In the presence of an intact upper urinary system, if the bladder has been removed or irreparably damaged or does not function adequately, urinary diversion is required. Diversion may also be appropriate for a patient with a grossly symptomatic bladder as a result of tumour, chronic infection or radiotherapy. It is also an alternative to a permanent indwelling catheter or intermittent self-catheterisation.

The standard urinary diversion is an ileal conduit. Another option is a neobladder, usually fashioned with a segment of ileum that is detubularised and made into a pouch and anastomosed to the proximal urethra. The ureters are anastomosed on to the pouch. The third option is a Mainz II pouch, described below, using a sigmoid colon pouch.

Ileal conduit

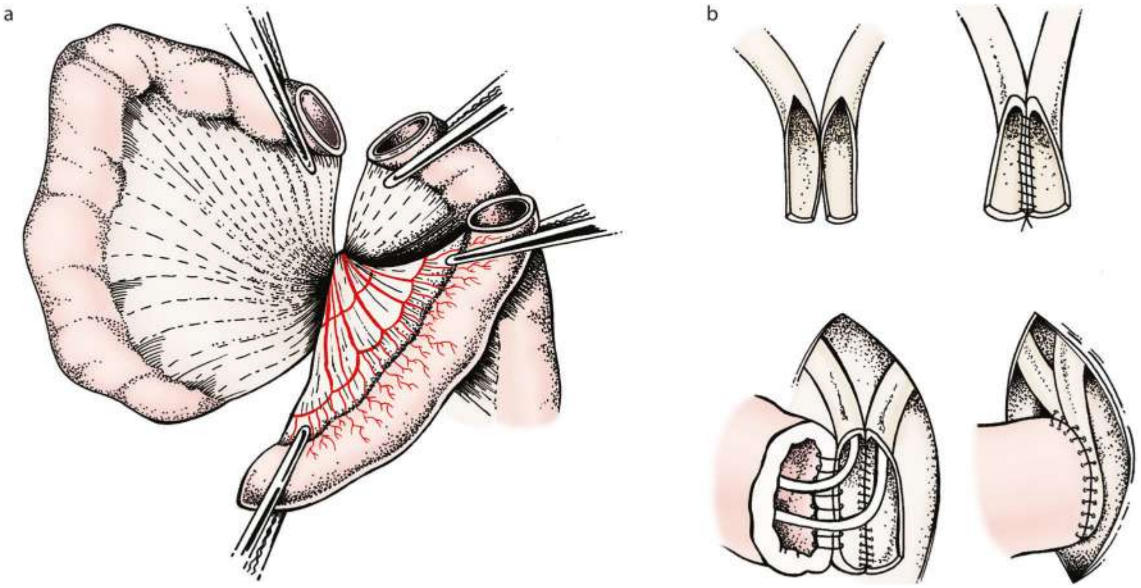
This is the standard procedure for urinary diversion. The ureters are reimplanted into an isolated small bowel conduit, which is brought out as a permanent urinary stoma. The stoma site is chosen, taking into consideration the body habitus, abdominal skin folds, etc. A loop of ileum, at least 15 cm from the ileocaecal valve, is isolated on its mesentery. The loop must be long enough to extend, without tension, from the midline posteriorly to about 5 cm beyond the site of the stoma, on the anterior abdominal wall. The ileal mesentery is divided sufficiently to allow the necessary mobility while preserving a good blood supply (Figure 25.18a). The loop will function as a urinary conduit ending as an ileostomy stoma. Small bowel continuity is re-established by an anastomosis anterior to the isolated loop.

Mobilising the caecum and sigmoid colon, the ureters are traced and divided as far distally as is practical. An appendicectomy may be performed. The left ureter is then tunnelled medially, under the pelvic mesocolon, to lie alongside the right ureter. The ureters are spatulated and anastomosed to the ileum separately, or together (Figure 25.18b). A kink or twist in the ureter can be ruled out by passing a feeding tube up the ureter. The distal end of the ileal conduit is then brought out, through the abdominal wall, as an ileostomy stoma, preferably through the lateral aspect of the rectus. Accurate mucosal apposition is important to prevent anastomotic strictures. Single J stents or infant feeding tubes can be used as splints for the ureters to the ileum. The latter needs to be anchored to the conduit with absorbable sutures. The anastomoses are stented for 2 weeks and a drain left *in situ*.

Sigma-rectum pouch (Mainz II pouch)

This procedure can be carried out in situations where a stoma is unacceptable or in areas where stoma appliances are unavailable or in short supply. However, there are more complications associated with this procedure. Ascending infection of the upper renal tract is more common, despite anti-reflux measures. Absorption of urine leads to metabolic disturbances, and urine continuously in contact with colonic mucosa is carcinogenic. The risk for malignancy at the site of the uretero-colonic anastomosis increases after 10 years, and regular colonoscopy is required for early detection.

The Mainz II rectosigmoid pouch creates a urinary reservoir for the urine using the rectosigmoid cavity with the bowel in continuity with the anal canal. The ureters are anastomosed to this reservoir. The prerequisites for this pouch are a competent anal sphincter, the absence of any benign or malignant pathologies in the rectosigmoid or pelvis, no prior history of pelvic radiation and normal renal function. The urine is stored in the rectosigmoid and passes via the anal canal mixed with stools. Adequate large bowel preparation is required. A rectal tube is placed prior to the



25.18 An ileal conduit. (a) A suitable loop of ileum is isolated. The divided ends of ileum are anastomosed anterior to the loop to restore continuity. (b) The ureters are implanted into the proximal end of the loop, the distal end of which is then brought through the abdominal wall as an end ileostomy. ⏎

surgery. In the supine position with the pelvis elevated, a lower midline incision is used.

After assessing the available length of the rectosigmoid, two stay sutures are placed at 3 and 9 o'clock positions at the level of the sacral promontory (Figure 25.19a). The descending colon is released up to the spleno-colic ligament and the bowel is folded on itself (Figure 25.19b). A 15–20 cm enterotomy is made on the isolated rectosigmoid colon along the anterior taenia coli (Figure 25.19b). A side-to-side anastomosis is fashioned between the edges of bowel close to each other on the concave side of the sigmoid colon (Figure 25.19c). A single-layer continuous seromuscular layer with a monofilament absorbable 4/0 suture and a separate 5/0 running suture for the mucosa is recommended.

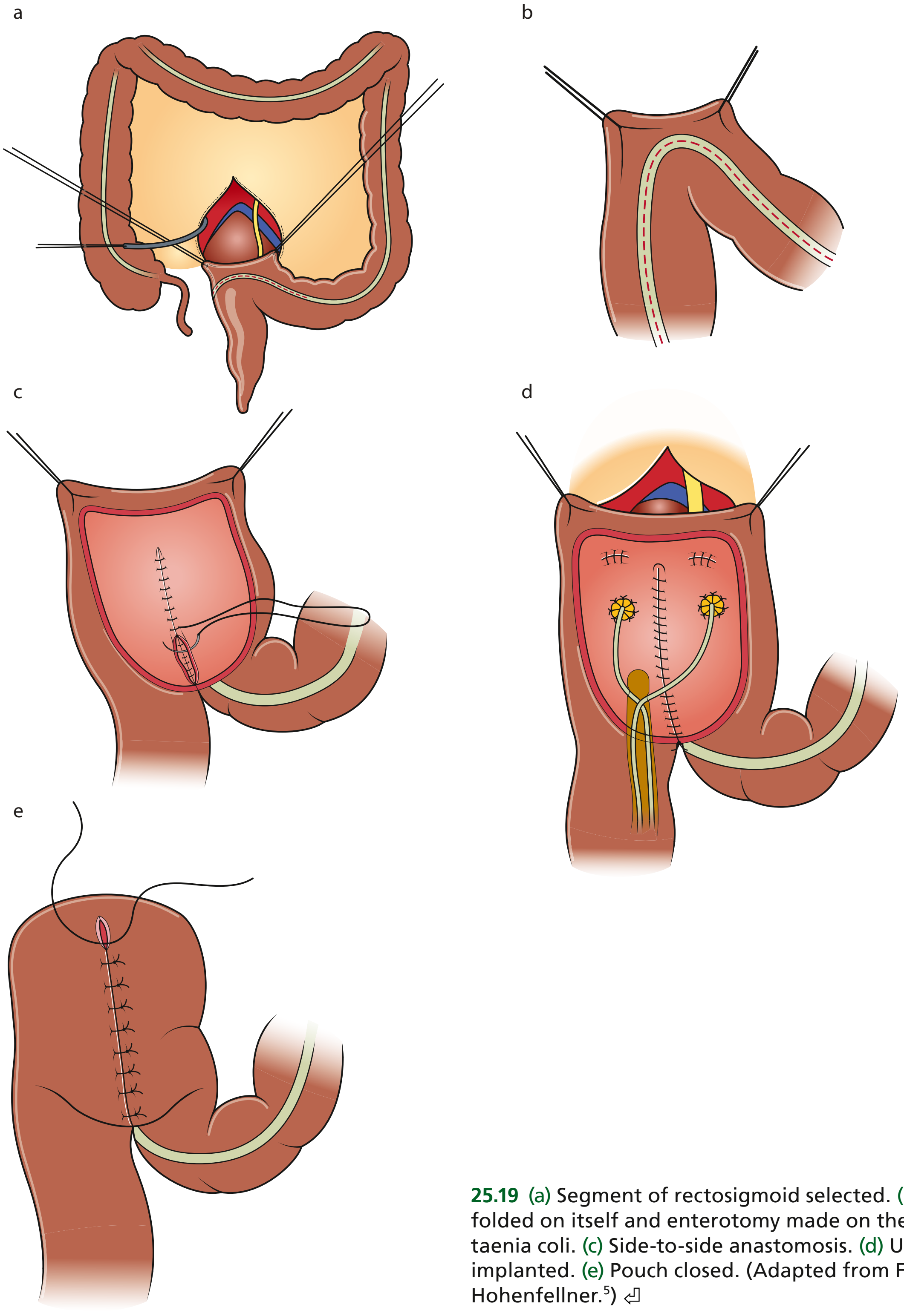
The ureters are dissected and delivered through a vessel-free window of the mesentery into an intraperitoneal position, at the level of the sacral promontory. Care is taken to avoid any twist, tension or kink of the ureters. This can be ensured by checking if a feeding tube passes up the ureter freely. The ureters are individually anastomosed to the posterior wall of the pouch through a submucosal tunnel to prevent reflux (Figure 25.19d). Interrupted 5/0 monofilament absorbable sutures are used and 6 Fr ureteric catheters are placed into the ureters and delivered into the rectal tube. The catheters are also fixed to the mucosa of the pouch with fine absorbable sutures.

The anterior wall of the pouch is then closed with interrupted 4/0 sutures in two layers, mucosa and seromuscular, from the caudal to the cranial end (Figure 25.19e). The mesenteric windows are closed and the pouch is covered with the mobilised greater omentum. The ureteric stents and rectal tube are fixed to the skin with separate non-absorbable sutures. The rectal tube is removed on the 5th postoperative day. The ureteric catheter fixations are kept for 8–10 days, after which they usually fall out spontaneously.

AUGMENTATION CYSTOPLASTY

In many developing countries, tuberculosis is still prevalent. Urinary tuberculosis may be asymptomatic or manifest with severe frequency and sterile pyuria. It may also be detected incidentally with calyceal dilatation, hydronephrosis and stricture of the ureter, and may lead to non-function if there is extensive damage. Bladder involvement often causes severe voiding symptoms and may manifest with a small contracted bladder. A voiding history by 'bladder diary' is important in decision-making.

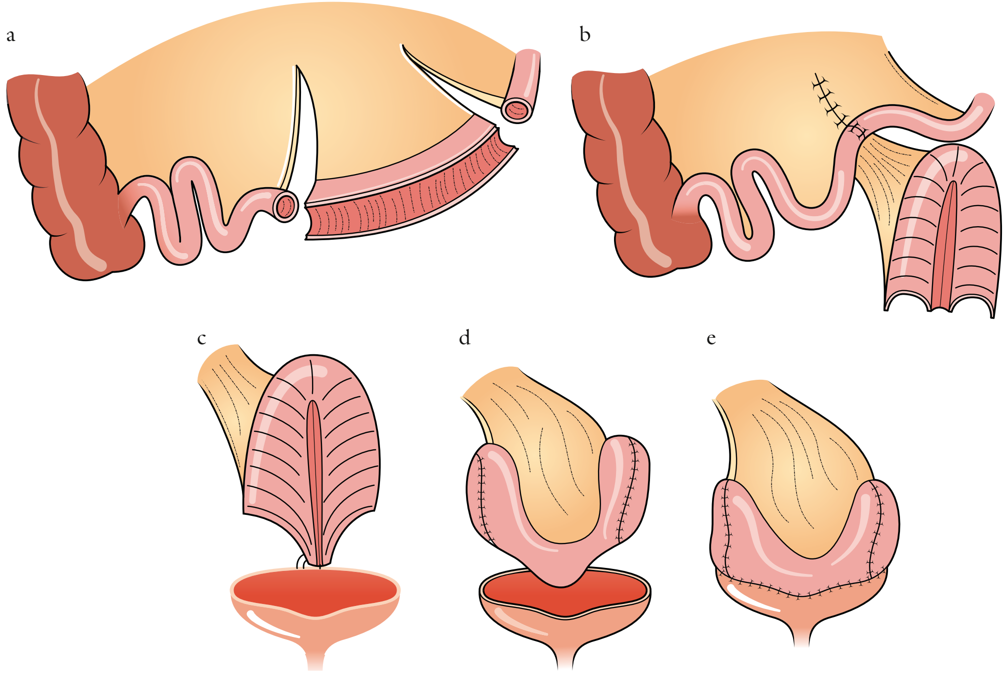
Imaging of the urinary system is by either IVU or a CT urogram. Surgical intervention (except DJ stent placement or nephrostomy) should not be planned in the initial months of anti-tubercular treatment. Adequate time should be given to allow the fibrosis that occurs after treatment to stabilise. A contracted bladder requires augmentation, and the ideal bowel segment is ileum, detubularised and made into a pouch (Figure 25.20). To prevent persistence of symptoms, the diseased bladder should be maximally



25.19 (a) Segment of rectosigmoid selected. (b) Bowel folded on itself and enterotomy made on the taenia coli. (c) Side-to-side anastomosis. (d) Ureters implanted. (e) Pouch closed. (Adapted from Fisch and Hohenfellner.[5]) ⏎

excised, up to the trigone if necessary. A wide opening of the pouch at the anastomosis to the bladder can prevent an hourglass deformity. If the ileum is unhealthy, which is not uncommon in tuberculosis, the caecum can be used without detubularisation and an appendicectomy can be performed. The ureter is reimplanted into the bowel and through the taenia coli if the caecum is used. If there is a non-functioning kidney, augmentation can be combined with a nephrectomy through a midline incision.

In neurovesical dysfunction, when the filling pressure of the bladder is high (poor compliance), an ileal



25.20 (a) Ileal segment isolated and detubularised. (b–d) Pouch fashioned. (e) Pouch anastomosed to the bladder. ⏎

augmentation cystoplasty is carried out after bivalving the bladder. This markedly reduces the resting and filling pressure. However, voiding will not be possible and clean intermittent self-catheterisation is required. Care has to be taken in a pregnant woman who has had a bladder augmentation if a caesarean section is needed, and it is best carried out with the assistance of a urologist.

PROSTATE

RETROPUBIC PROSTATECTOMY

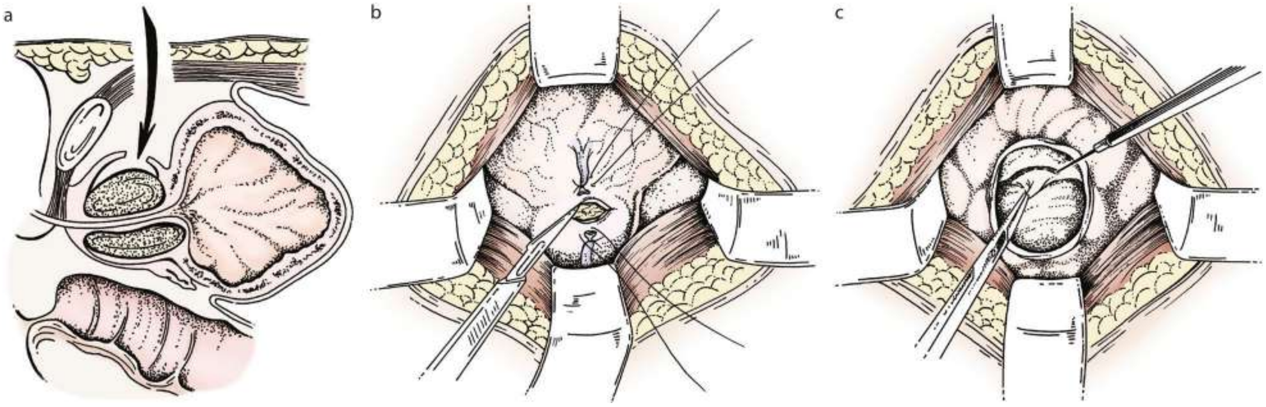
In benign pathology, the enlarged adenoma within the prostate can be removed at open surgery via either a retropubic or a transvesical route. The retropubic approach has remained in common use, but its indications are dwindling, as transurethral resection, laser ablation and enucleation have become the standard treatment in experienced trained hands for even very large prostates.

Operative procedure

A cystoscopy is performed before a retropubic prostatectomy to exclude any associated bladder pathology. The patient is then placed supine and the table tilted head-down. The extraperitoneal plane is entered via a lower midline or transverse suprapubic incision (Figure 25.21a). The wound is held open with a self-retaining retractor and pressure is exerted on the bladder with a swab on a stick. This tilts the prostate away from the pubis and exposes the fat on the surface of the prostatic capsule. The vessels within this fat must be secured with coagulation diathermy or ligation so that the fat can be cleared to expose the capsule and the fibres of the puboprostatic ligaments meeting in a V at the bladder neck. The prostatic capsule incision is planned a centimetre or two below the bladder neck. Deep absorbable stay sutures are placed above and below the point chosen for this incision. These sutures are tied to reduce bleeding from the capsule (Figure 25.21b). A generous transverse incision is then made through the prostatic capsule to expose the white surface of the adenoma.

The anterior commissure of the prostatic lobes is then opened with the surgeon's index finger to enter the prostatic urethra and feel the verumontanum and the prostatic adenoma from within the urethra. Pressure with the index finger posterolaterally just above the level of the verumontanum will produce a split in the urethra. This split can be extended around the apex of the prostatic adenoma by further digital pressure and the remainder of the plane between the adenoma and the prostatic capsule is then freed in a similar manner. The adenomatous lobe is delivered out of the capsule, and its remaining attachment at the bladder neck is divided with scissors. The procedure is repeated on the other side.

The prostatic cavity is packed with swabs and attention is turned to the middle lobe. The top of the



25.21 Retropubic prostatectomy. (a) The preperitoneal space is entered suprapubically. (b) The anterior prostatic capsule is completely cleared of fat and veins and is incised transversely between stay sutures. (c) The bladder neck has been grasped with tissue forceps and the middle lobe of the prostate is excised. Identification of the ureteric orifices is important at this stage to avoid damaging them when the bladder neck suture is placed. ⏎

median lobe is grasped in tissue forceps and drawn forwards, while a small swab on a stick, placed in the base of the bladder, is drawn anteriorly. This will demonstrate the interureteric bar and the ureteric orifices. A diathermy incision is commenced in the midline behind the median lobe (Figure 25.21c). The incision is carried anterolaterally in front of each ureteric orifice to the bladder neck. The posterior prostatic urethra can then be divided with scissors just above the level of the verumontanum and the enucleation of the median lobe completed.

Haemostasis can be improved by suturing the posterior bladder mucosa to the bladder neck with an absorbable suture. The first two sutures of the capsular closure are inserted beyond each end of the capsular opening. A strong absorbable material is used and a deep bite is taken. Tying of these sutures reduces the prostatic capsular bleeding, while the prostatic cavity is checked for bleeding points and sealed with diathermy coagulation. Finally, closure of the capsule is completed from both ends with a haemostatic continuous suture. Pressure on the bladder, similar to that used before the capsule was opened, will improve access for closure. A rigid 22/24 three-way catheter is guided into the bladder before the capsular closure is completed. The tip will tend to catch on the bladder neck and has to be lifted anteriorly. A finger in the rectum will help guide the catheter into the bladder. Following capsular closure, the catheter balloon is inflated with 30–40 mL of water and the bladder filled to check for leakage at the closure site. Additional sutures can be placed if there is any leakage or continuing suture-line haemorrhage. When there is excessive bleeding from the prostatic bed, an additional suprapubic catheter can be placed through the anterior wall of the bladder before the capsular closure is complete. This can be used for extra irrigation.

A retropubic drain is kept for the first 48 hours. The urethral catheter is placed on continuous irrigation and continuous drainage. Irrigation can be stopped when bleeding reduces. The catheter can be removed after 5–6 days. A blocked catheter requires saline irrigation with a bladder syringe. Occasionally, a patient has to be taken back to the theatre for excessive bleeding. A resectoscope is passed, the clot washed out and bleeding points sought, but rarely are precise bleeding points found. Usually, even if no bleeding point is identified, the bleeding settles after a bladder washout.

TRANSVESICAL PROSTATECTOMY

This can be combined with removal of a bladder calculus. As in a retropubic prostatectomy, the anterior commissure of the prostatic lobes is opened but from within the bladder. Pressure with the index finger anteriorly will produce a split in the urethra. This split can be extended around the apex of the prostatic adenoma by further digital pressure, and the remainder of the plane between the adenoma and the prostatic capsule is freed in a similar manner. The adenomatous lobe is delivered out of the capsule and its remaining attachment at the bladder neck is divided with scissors. The procedure is repeated on the other side. The median lobe is then enucleated.

Haemostasis is achieved in the same way as in a retropubic prostatectomy.

RADICAL PROSTATECTOMY

Radical retropubic prostatectomy is one of the treatment options for early organ confined prostate cancer. It is performed after representative biopsies and in those with a life expectancy of over 10 years. The main complications are incontinence and erectile dysfunction.

ENDOSCOPIC PROCEDURES

Endoscopic surgery for the bladder and prostate is routinely carried out by urologists. However, a general surgeon practising in smaller hospitals, with no emergency urological service, may be required to carry out some simple endoscopic procedures. A cystoscope can be passed to irrigate the bladder for clot retention. A resectoscope has the added advantage that diathermy coagulation of a bleeding area or resection and coagulation is also possible. A three-way urethral catheter is then inserted and irrigation of the bladder continued to prevent further clot formation.

CYSTOSCOPY

Cystoscopy is the inspection of the bladder by the passage of a cystoscope through the urethra.

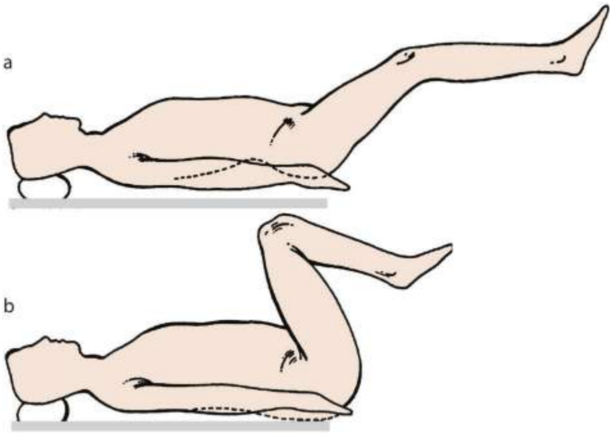
Flexible fibreoptic cystoscope

A flexible fibreoptic cystoscope, well lubricated with local anaesthetic gel, can be passed with minimal discomfort in both male and female patients. The passage through the urethra is under direct vision, and excellent views of the bladder and urethra are obtained. However, the working channels are small but can be used to remove stents. A flexible cystoscope is not as efficient for irrigating intravesical clots or for undertaking any major operative procedure.

Rigid cystoscopy

There are two types of rigid cystoscopes. The integrated scope is a single-piece instrument and the other type has three parts: the sheath, the bridge and a telescope. A rigid cystoscope is passed under vision with the patient in the lithotomy position (Figure 25.22a, b). A rigid scope can usually be passed easily in women but, in men, the angulations of the urethra require some form of general or regional anaesthesia.

In a man, insertion of a cystoscope is commenced with the penis held vertically and then orientated to enter the bulbar and, subsequently, the membranous urethra. It is then directed towards the umbilicus, past the verumontanum until the bladder is entered. The flow of irrigation fluid holds the urethra open ahead of the scope and minimises trauma. At all times, the lumen should be kept in view. In addition to the telescope and the irrigation channel, it is possible to pass forceps for biopsy or instruments for grasping intravesical objects such as stones or a stent. Ureteric catheters or stents can be passed through the cystoscope and into the ureteric orifices. For clot evacuation, a bladder wash can be performed using an Ellik evacuator or a Toomey syringe. Integrated scopes cannot be used for bladder washout.



25.22 (a) The optimal position for urological procedures. (b) Further flexion at the hip may be necessary for certain perineal procedures. ⏎

URETERIC CANNULATION AND DOUBLE J STENTING

Ureteric cannulation is undertaken under intermittent X-ray monitoring. The cystoscope is introduced into the bladder under vision and the bladder is drained. The ureteric orifice is identified by keeping the scope at the bladder neck, in the midline, and tracing the interureteric bar laterally. The ureteric catheter is introduced through the scope and positioned close to the orifice. A floppy tip guide wire is passed carefully through the ureteric catheter and manipulated into the orifice under screening. The ureteric catheter is then advanced over the wire for a few centimetres and contrast is injected to delineate the ureter. The guide wire is reinserted into the ureteric catheter and advanced up to the renal pelvis followed by the ureteric catheter over the guide wire. The urethral catheter is inserted and the ureteric catheter is fixed on to the urethral catheter.

Double J stenting

The above procedure is repeated but the guide wire is left in the renal pelvis and the ureteric catheter is withdrawn. The double J stent is passed over the guide wire up to the pelvis using a pusher. The wire is withdrawn to position the upper curl in the pelvis and the lower curl in the bladder under radiological screening. The position is confirmed postoperatively with a plain film performed to check the position. Follow-up is essential, as stents may migrate, and there is a risk of a retained stent if the patient is lost to follow-up.

Ureteroscopy

Ureteric calculi are amenable to endoscopic treatment. However, management of upper ureteric calculi

25.23 Ureteroscope, pneumatic lithotripter and light cable. ⏎

can be complex and is best performed by surgeons who have had training in endoscopic urology. The essential equipment required is a cystoscope, a semi-rigid ureteroscope, a stone grasper and intraoperative access to fluoroscopy with a C arm. The pneumatic lithotripter offers a sturdy and easy to maintain energy source using compressed air (Figure 25.23). In a remote hospital, if access to compressed air is difficult at any time, oxygen from a cylinder can be used instead. The disposable items needed are hydrophilic guide wires, open-ended ureteric catheters and double J stents.

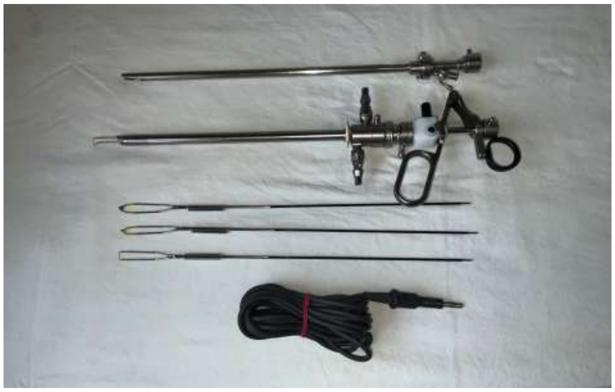
A preoperative imaging study is mandatory and a renal functional study can also be performed in addition if there is hydronephrosis or a long-standing obstruction. The urine should be sterile, so a urine culture should be performed beforehand. It is recommended to perform a plain X-ray on the day of the procedure to confirm the presence and position of the calculus. A single dose of intravenous antibiotics is given at the start of the procedure. In the presence of positive culture antibiotic therapy should be started at least 48 hours prior to the procedure and continued postoperatively. The ureter is cannulated using a hydrophilic guide wire to access the ureteric orifice and a retrograde study is performed to document the site of the calculus and the upper urinary tract. A floppy tip guide wire is passed up into the kidney, beyond the stone, and the cystoscope is removed. An 8 Fr feeding tube is inserted into the urethra to drain the bladder. The ureteroscope is manoeuvred into the ureteric orifice, keeping the tip of the scope below the wire and using the wire to lift the roof of the orifice to allow the beak to enter first. The scope is passed up to the calculus followed by the pneumatic probe. The calculus is fragmented in a controlled manner to avoid retropulsion. Damage to the scope can be prevented by keeping it slightly away from the calculus at the time of fragmentation. Stone fragmentation can obscure the vision transiently. As flushing risks the chance of retropulsion, shutting the inflow and opening the outlet to allow drainage usually clears the field of vision. When the calculus migrates upwards, it can be grasped and brought down the ureter. Suction applied with a syringe connected to the outlet, with the inlet closed, can also achieve the same objective. Shutting the inflow intermittently and allowing drainage helps reduce the pressure in the system and reduces potential sepsis. Under fluoroscopic guidance, the calculus is fragmented. It is not necessary to remove the very fine fragments. A double J stent is left *in situ* after the procedure. If the scope does not pass easily upwards, it is withdrawn and a double J stent is inserted. The procedure can be attempted again after a few weeks when the ureter is dilated. If the calculus is impacted and does not allow the floppy wire to go beyond, the ureteric catheter is positioned about a centimetre below the calculus under fluoroscopy, the wire is removed and a gentle flush is performed using 1 mL of saline. Further attempts are then made with the hydrophilic guide wire. The calculus should not be fragmented without a wire across the impacted stone unless assisted by a urologist. A false passage, ureteric perforation and sepsis are potential complications. In such a situation, it is then better to divert the kidney obstruction with a percutaneous nephrostomy and attempt a ureteroscopy after the oedema has subsided.

Transurethral cystolithotripsy

This is ideally suited for stones of less than 2 cm. Larger calculi are better treated by percutaneous cystolithotripsy or open cystolithotomy.

The equipment needed includes a nephroscope with an outer sheath, graspers, a Toomey syringe and an energy source such as a pneumatic lithotripter. The nephroscope (Figure 25.24) is introduced into the bladder and using the probe the stone is fragmented and washed out with the Toomey syringe. A urethral catheter is left for at least 24 hours.

25.24 Nephroscope. ⏎



25.25 Visual obturator, resectoscope with working element, ball electrode, Collin's knife electrode, loop and high-frequency cable. ⏎

TRANSURETHRAL RESECTION: GENERAL PRINCIPLES

Endoscopic resection of bladder tumours and of benign and malignant prostatic tissue forms a major part of urological practice. For any endoscopic resection, an insulated resectoscope is required. The working element, which can be moved to and fro within the resectoscope sheath, and the telescope are important components. The diathermy loop, which may be either a wire for cutting or a ball for coagulation, passes through the working element (Figure 25.25). The procedure is performed with the video image on screen.

Saline should not be used as an irrigating fluid, as it forms an electroconductive solution that interferes with the diathermy current. Sterile water is also contraindicated when there is a significant danger of it entering open veins as water absorption risks haemolysis and death. This is of particular importance in prostatic resection. Glycine (1.5%) is the irrigating fluid used for resection. Metabolic problems such as hyponatraemia can occur with absorption of large quantities during a prolonged resection (transurethral resection syndrome). Saline can be used as an irrigating fluid if a bipolar resectoscope is used.

Initially, a cystoscopy is carried out, ruling out bladder tumour or calculus and the presence of a median lobe. If there is a need for resection, the urethra is calibrated and, if necessary, a urethrotomy is performed to accommodate the resectoscope. The external urethral meatus is frequently the narrowest portion of the urethra.

Transurethral resection of the prostate is the standard operation for urinary retention or severe urinary symptoms attributable to prostatic obstruction. A retropubic prostatectomy is a safer option in the hands of a general surgeon without endoscopic expertise, and is a suitable alternative except for obstruction from a malignant prostate.

It may not be necessary to resect small obstructing glands, as they can be treated by a bladder neck incision. This is a full-thickness cut made from below one of the ureteric orifices, through the prostatic capsule to the level of the verumontanum. After this procedure, the bladder neck can be seen to 'spring open'. However, larger prostates need resection.

The object of the resection is to remove the central adenomatous tissue, while preserving the prostatic capsule. For full operative details, the reader should refer to a standard textbook on transurethral resection. The resectoscope is passed into the bladder. The ureteric orifices are identified. There are various methods of resection. The authors' preference is to resect to the floor extending from the bladder neck to the verumontanum to allow the free flow of irrigation fluid especially if there is a median lobe. The channel is deepened until the prostatic capsule is seen and extended all around resecting the adenoma completely on either side. The resected chips are evacuated using an Ellik evacuator. Haemostasis is secured. If vision is lost due to severe bleeding, the resection is stopped, haemostasis is obtained and a catheter is inserted.

At the end of the procedure, after haemostasis is achieved, the bladder is drained with a stiff 22/24 three-way catheter and irrigated with normal saline.

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Gynaecology and obstetrics for the general surgeon

26

Anne George Cherian and Arpit Jacob Mathew

Not infrequently, the general surgeon, when performing a laparotomy, encounters an unexpected gynaecological condition, the management of which could cause some doubt and anxiety. The surgeon can usually call on the assistance of a gynaecological colleague, and should do so if at all possible. However, on occasion, when access to a gynaecological opinion is not possible, the general surgeon must accept responsibility for deciding what, if any, operative procedure is indicated and for mastering the techniques required. This chapter is mainly for such guidance.

There are some general surgeons working in small remote hospitals who are offering a basic, but reasonably comprehensive, obstetric and gynaecological service. This chapter cannot cover their operative surgical needs, and further training and reading are recommended.[1–4] There are, however, other surgeons whose normal practice does not include obstetrics or gynaecology but who may be summoned unexpectedly as the only available surgeon to operate in a life-threatening obstetric or gynaecological emergency. These situations are covered briefly in the following text.

Many of the scenarios outlined in this chapter would ideally be treated by less invasive procedures if a preoperative diagnosis could have been established and if the necessary equipment and expertise were available. For example, many ectopic pregnancies can be managed by medical treatment or laparoscopically, and massive obstetric haemorrhage may sometimes be best controlled by embolisation of pelvic vessels. However, on the occasions when a general surgeon has to be involved in an obstetric or gynaecological emergency, these techniques are seldom an option.

SURGICAL ANATOMY

The female genital tract, which lies between the rectum and the bladder, is confined to the pelvis, except in pregnancy.

THE VAGINA

The vagina lies in close proximity to the bladder and urethra anteriorly and to the rectum and anus posteriorly. Below the peritoneal reflection, the vaginal and rectal walls are separated by the rectovaginal septum and above the peritoneal reflection by the rectovaginal pouch (pouch of Douglas). The vault of the vagina is invaginated anteriorly by the uterine cervix, which divides the vault into anterior, lateral and posterior fornices. The ureters and the uterine arteries are closely related to the lateral fornices.

The *labia majora* skin folds lie on either side of the vaginal introitus, with the smaller *labia minora* medially. Flanking the vaginal introitus are *Bartholin's glands* and their ducts, which open into the vagina distal to the hymen.

THE UTERUS

The uterus lies between the bladder and the rectum, as a mainly intraperitoneal organ. Anteriorly, the peritoneum is reflected onto the upper surface of the bladder from the shallow *uterovesical pouch*; posteriorly, the peritoneum sweeps downwards over the posterior fornix and then is reflected onto the anterior aspect of the mid rectum, thus forming the *rectovaginal pouch*. The uterine *cervix* is below the peritoneal reflection. The supravaginal portion of the cervix is related to the bladder anteriorly, which it is connected to by some loose fibrous strands. The peritoneal layer is incomplete laterally due to the insertion of the Fallopian tubes and the round and ovarian ligaments into the uterus and, below this level, the two sheets of peritoneum, which constitute the broad ligament, leave a thin bare area:

- The *Fallopian (uterine) tubes* lie along the upper free border of the broad ligament with the upper part of the ligament being the *mesosalpinx*. Medially, the

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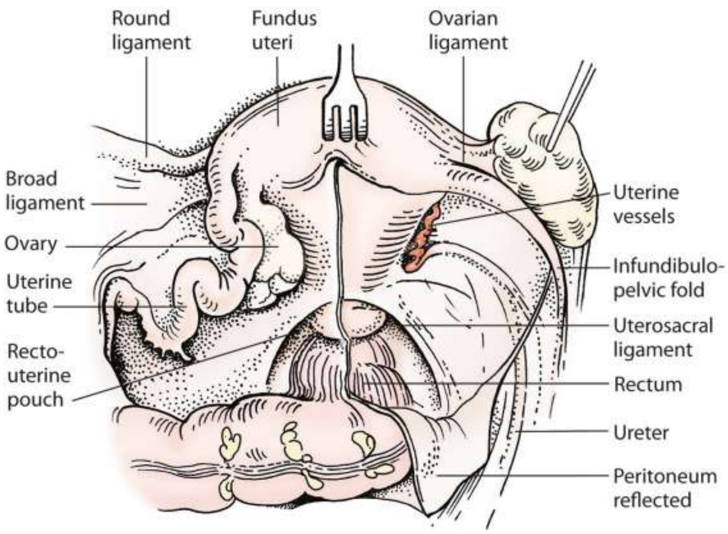


26.1 Anatomy of the female pelvis, viewed from above at laparotomy. ⏎

tubes traverse the uterine wall to open into the upper angle of the uterine cavity. The lateral ends emerge from the posterior layer of the broad ligament and divide into multiple finger-like processes termed *fimbriae*. This open lateral end is in communication with the peritoneal cavity and lies close to the ovary.

- The *broad ligament* is a fold of peritoneum that stretches from the lateral wall of the uterus to the pelvic sidewall (Figure 26.1). Its upper free border contains the uterine tube in its medial four-fifths; its lateral one-fifth containing the ovarian vessels constitutes the *infundibulopelvic ligament*. The uterine vessels lie between the layers of the ligament, first along its base and then close to its attachment to the side of the uterus.
- The *round ligament* raises a ridge on the anterior surface of the broad ligament as it passes from the uterus to the deep inguinal ring.

THE OVARY

The ovary lies on the lateral part of the posterior surface of the broad ligament, to which it is attached by a small fold of peritoneum, the *mesovarium*. Apart from its mesovarian attachment, the ovary is devoid of peritoneal covering. A normal ovary is 3–5 cm in length. It is greyish-white in colour, but its size, shape and surface can vary considerably throughout the menstrual cycle. In prepubertal girls, the ovary is smooth but, following puberty, the surface becomes wrinkled and scarred, and it may contain several or single cysts. The ovary is primarily attached to the broad ligament and pelvic sidewall:

- The *ovarian ligament* attaches the ovary to the uterus and raises a small ridge on the posterior surface of the broad ligament.
- The *infundibulopelvic ligament* attaches the ovary to the pelvic sidewall and carries the ovarian vessels.

VESSELS

The female genital organs have a rich blood supply and, in pregnancy, the uterine arteries enlarge substantially:

- The *uterine artery* arises from the anterior division of the internal iliac; it runs forwards to the base of the broad ligament and then medially within it, above the lateral fornix of the vagina, where it crosses the ureter 1–2 cm lateral to the supravaginal part of the cervix; finally, it runs upwards along the lateral margin of the uterus, to which it gives numerous branches, including one to the uterine tube.
- The *ovarian artery* arises from the aorta, a little below the renal artery, and runs down the posterior abdominal wall; it then passes forwards and medially to reach the ovary via the infundibulopelvic ligament.

ANTERIOR PERINEAL PROBLEMS

BARTHOLIN’S ABSCESS

A Bartholin’s gland may distend and form a cyst if the duct becomes blocked. An infected cyst forms a painful abscess. An incision and drainage with placement of a Foley catheter, or other drainage tube, in the out-patient unit may be performed. Alternatively, a marsupialisation may be performed, which preserves the gland’s lubricating function, and, if an opening of adequate size is created, there is a low risk of recurrence.

Operative procedure (marsupialisation)

Bartholin's glands are found at the 5 and 7 o'clock positions. A 1–2 cm elliptical incision is made over the convexity of the abscess on the hymenal side, so that the opening will drain into the vagina. The skin ellipse is excised, after which a similar ellipse is excised from the cyst wall and the abscess drained. It is preferable, but not always possible, to excise these two ellipses separately. A series of fine absorbable interrupted sutures is placed around the circumference to include both layers, forming an elliptical opening. The large size of the opening looks alarming initially, but once all inflammation has settled the final diameter is much smaller.

VESICOVAGINAL FISTULAE

These fistulae are common in areas where skilled intervention is unavailable during an obstructed labour. The pressure of the fetal head against the pubic symphysis causes ischaemic necrosis of the vaginal and bladder walls before finally, after several days of obstructed labour, a stillborn baby is delivered. Although repair should rightly be viewed as a specialised uro-gynaecological challenge, in practice many of these injuries are repaired by generalists, often in relatively remote hospitals. Expertise has been developed in the Addis Ababa Fistula Hospital (Ethiopia), and this hospital's training courses and video are recommended to surgeons wishing to undertake these repairs.[5] No specialised equipment is needed.

Operative procedure

Most repairs are performed from the perineum and, if not identified intraoperatively during caesarean section, must be attempted only after 3–6 months. A cystoscopy should be performed and the ureteric orifices stented. A urethral catheter is passed and will be left on free drainage for 2 weeks postoperatively while the bladder heals. The plane between the bladder and the vagina is infiltrated with a dilute adrenaline solution, and the two organs are separated by a combination of sharp and blunt dissection. Extensive mobilisation of the tissues is required. The bladder and vagina are repaired as separate layers with absorbable sutures. A Martius flap interposition with the labial fat pad (see Chapter 15) or interposition grafts with a variety of flaps[6–17] have proved valuable in bringing well-vascularised tissue between the two suture lines when tissue loss has been significant.

PERINEAL THIRD-DEGREE TEARS WITH ANAL SPHINCTER DISRUPTION

The repair of these obstetric injuries to the anal sphincters is discussed in Chapter 15.

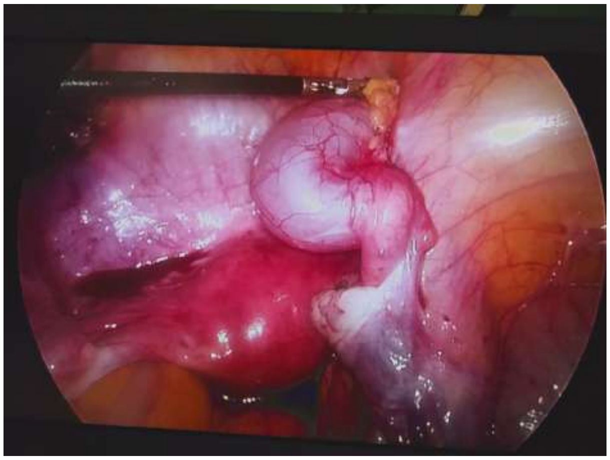
RECTOCELE

Rectoceles are commonly the result of obstetric damage to the rectovaginal septum. Many require no operative intervention, but those that come to surgery may be operated on by either gynaecologists or coloproctologists. The surgical options are discussed in Chapter 15.

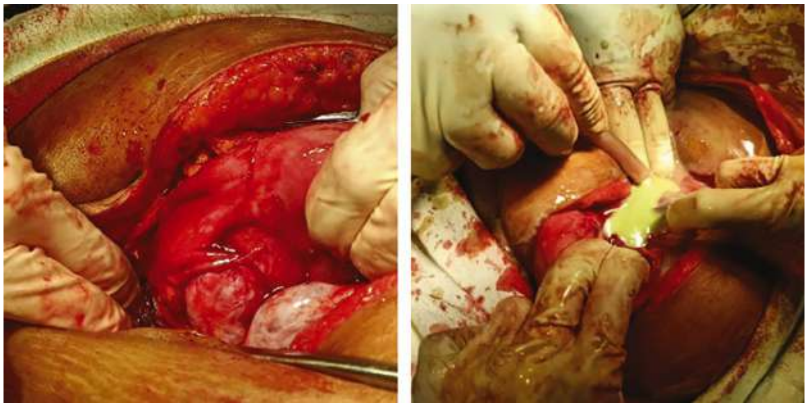
CONDITIONS AFFECTING THE FALLOPIAN TUBE

SALPINGITIS

Pelvic peritonitis from salpingitis may be indistinguishable preoperatively from pelvic peritonitis secondary to appendicitis. Even after the abdomen has been opened, the diagnosis may initially still be unclear. Fallopian tubes lying within an appendix abscess will be inflamed, and an appendix lying within the pus of a severe salpingitis will show serosal inflammation (see Chapter 13). Once the diagnosis of salpingitis is established, only a bacteriological swab and peritoneal toilet are required before closure of the abdominal incision and the instigation of antibiotic therapy. An endocervical swab should also be taken to check for *Chlamydia*. Salpingitis in a scarred blocked tube may form a pyosalpinx or hydrosalpinx (Figure 26.2). This requires drainage either by simple incision



26.2 Right hydrosalpinx. ⏎



26.3 Tubo-ovarian abscess. ⏎

or, preferably, by a salpingectomy, ideally performed laparoscopically.

TUBO-OVARIAN ABSCESS

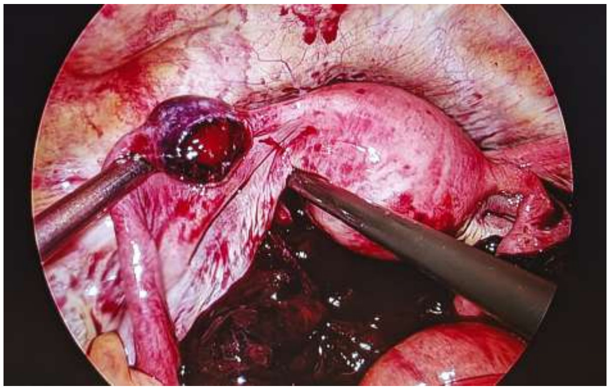
Pelvic inflammatory disease can present as an acute abdomen. Occasionally, it can lead to abscess formation that incorporates the Fallopian tube and ovary. This is known as a tubo-ovarian abscess (Figure 26.3). The tubo-ovarian abscess can involve other adjacent pelvic organs such as the bowel and bladder. Aggressive medical and/or surgical management is required, and rupture can lead to sepsis. Treatment modalities include antibiotic therapy, minimally invasive drainage procedures, open or laparoscopic surgery or a combination of all of these approaches.

The management of a tubo-ovarian abscess involves diagnosis, removal of as much of the abscess cavity and inflammatory fluid and debris as possible, and copious irrigation to remove as much infective material as possible.

RUPTURED ECTOPIC PREGNANCY

Most ectopic pregnancies implant in the extrauterine portion of the Fallopian tube, and rupture occurs at around 5–7 weeks' gestation (Figure 26.4). However, an ectopic pregnancy in the intramural portion of the tube, or in the cervix, ruptures later, at 9–16 weeks. Rarely, rupture can lead to fetal implantation on abdominal organs and bowel.

Rupture of an ectopic pregnancy is usually an emergency. It should always be suspected in a woman of childbearing years who has collapsed with shock and lower abdominal pain. Classically, there is a history of a missed period, signs and symptoms of early pregnancy, and per vaginal bleeding, but frequently these clues are absent, and even a previous sterilisation operation does not preclude the diagnosis. Haemodynamically unstable patients with this acute presentation require simultaneous resuscitation and surgical exploration and cannot be referred elsewhere if a gynaecologist is not available.



26.4 Ruptured left ectopic pregnancy. ⏎

However, an ectopic pregnancy can sometimes be a subacute event. The signs and symptoms are largely related to whether the ectopic pregnancy is intact, has aborted via the Fallopian tube into the peritoneal cavity or has ruptured through the tubal wall into the peritoneum or into the broad ligament. Pelvic peritoneal irritation may produce tenesmus and diarrhoea or mimic appendicitis. Intraperitoneal blood can irritate the diaphragm and produce shoulder tip pain. If the diagnosis of an ectopic pregnancy has not been suspected preoperatively, a general surgeon may have proceeded to surgery with an incorrect preoperative diagnosis. It is therefore *imperative to do a pregnancy test* in women of reproductive age who present with an acute abdomen.

Clinical examination will depend on whether the ectopic pregnancy is ruptured or unruptured. If presenting early, the patient will be stable but, as bleeding increases, there may be signs of haemodynamic instability. Abdominal palpation may reveal tenderness in 90% of patients, and the classic sign of a tubal pregnancy is the elicitation of pain on the affected side on movement of the cervix (cervical excitation test).

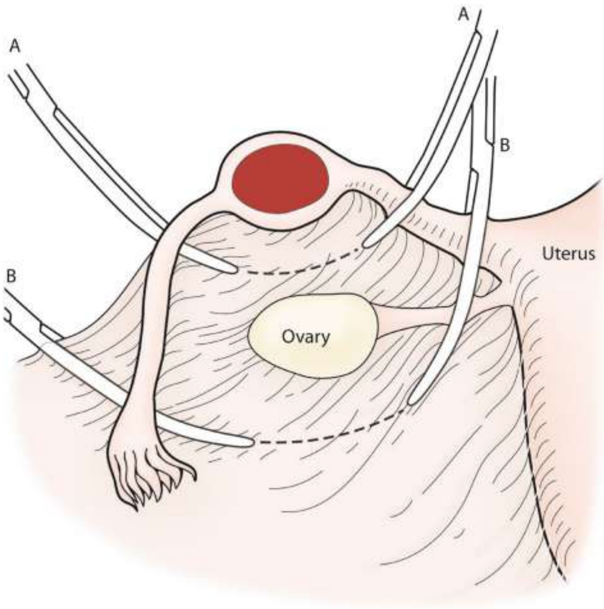
Diagnosis can be confirmed with an ultrasound. Culdocentesis is rarely used but may be done in resource-constrained settings. It involves aspiration of the contents of the pouch of Douglas to determine whether blood is present.

In women who are bleeding profusely, the first priority is to control the haemorrhage. After the peritoneal cavity has been entered, it may be difficult to identify the affected tube because of the amount of blood in the pelvis and the continuing bleeding. A hand inserted into the blood-filled pelvis can feel the uterus, draw it up and then palpate the tubes to identify the affected side. Digital compression of the broad ligament, proximal and distal to the mass, will provide temporary control of haemorrhage until a clamp can be applied. Autotransfusion of the intraperitoneal blood is occasionally possible (see Chapter 17).

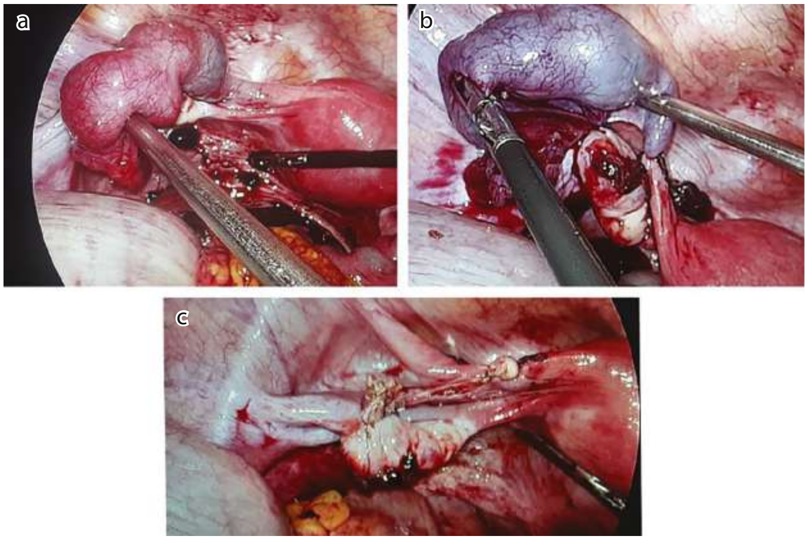
Surgical options

There are a number of surgical options to treat ruptured ectopic pregnancies. Laparoscopy is the preferred modality, although laparotomy is widely performed. Unilateral simple salpingectomy has the benefits of controlling the haemorrhage, excising the whole pregnancy and not leaving a damaged tube to give rise to a further ectopic. In the presence of a healthy contralateral tube, a salpingectomy is preferred.[18] If the other tube is absent or severely damaged, and further children are wanted, a conservative operation, such as a salpingotomy, should be considered. If the patient's family is complete, bilateral salpingectomy should be considered.

Simple salpingectomy The affected tube is clamped close to its uterine end. While the tube is held up by Babcock forceps, the mesosalpinx is divided close to the tube, between a series of clamps (A–A in Figure 26.5; also Figure 26.6). The tube is removed and the pedicles are tied off with absorbable transfixion sutures. If approached laparoscopically, the mesosalpinx and pedicle can be divided with a



26.5 Salpingectomy for ectopic pregnancy. Clamps are placed on the mesosalpinx and on the uterine end of the tube (A–A). The infundibulopelvic ligament carrying the ovarian vessels is preserved. If the decision is made to remove the ovary along with the tube (a salpingo-oophorectomy), then the tissue between the clamps (B–B) is removed. ⏎



26.6 Left salpingectomy for tubal ectopic pregnancy. (a) Left ectopic pregnancy. (b) Pedicle of the tube and mesosalpinx ligated. (c) After specimen removal. ⏎

vessel-sealing device or tied using intracorporeal knots. The peritoneal cavity is cleared of blood and blood clots.

Fimbrial evacuation If the tubal pregnancy is about to abort from the fimbrial end, then an attempt to complete the process by gentle pressure is permissible, but care should be taken to leave no trophoblastic tissue behind.

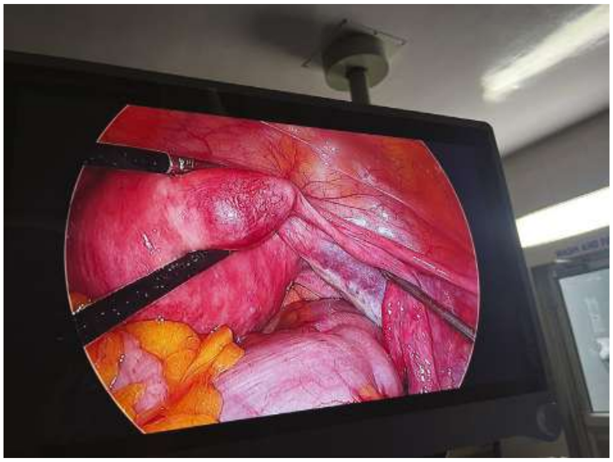
Linear salpingostomy The incision (1–2 cm) is made on the antimesenteric border of the Fallopian tube and the products are gently flushed out of the tube using gentle mechanical pressure. Haemostasis is secured. The incision is not sutured but left to heal on its own. The drawbacks of a salpingostomy are the risk of recurrence of an ectopic pregnancy in the same tube and the risk of persistent trophoblastic tissue in the tube.

Atypical ectopic pregnancy

The three rarer forms of ectopic pregnancy described below present with atypical symptoms and signs.

Interstitial (cornual) pregnancy Ectopic gestation in the intramural portion of the Fallopian tube (Figure 26.7), although rare, can be the cause of rapid and profuse haemorrhage. Cornual resection to remove the whole pregnancy is followed by a two-layer haemostatic repair of the uterus with deep interrupted sutures. When haemorrhage cannot be controlled, a subtotal or total hysterectomy may be necessary.

Cervical ectopic pregnancy If the cervical pregnancy is detected early, with low human chorionic gonadotrophin (hCG) levels, conservative management may be attempted with methotrexate. A gestational age of more than 9^{+0} weeks, β-hCG levels greater than 10,000 IU/L, a crown–rump length greater than 10 mm and fetal cardiac activity were shown to be associated with a higher risk of primary failure of the treatment of cervical ectopic pregnancy with systemic methotrexate.[18]



26.7 Cornual pregnancy. ⏎

If conservative management is not possible or the patient presents with massive haemorrhage, the only treatment may be a total hysterectomy. Sometimes, however, it may be possible to save the uterus if haemorrhage can be controlled either by tamponade with a Foley catheter or by embolisation.

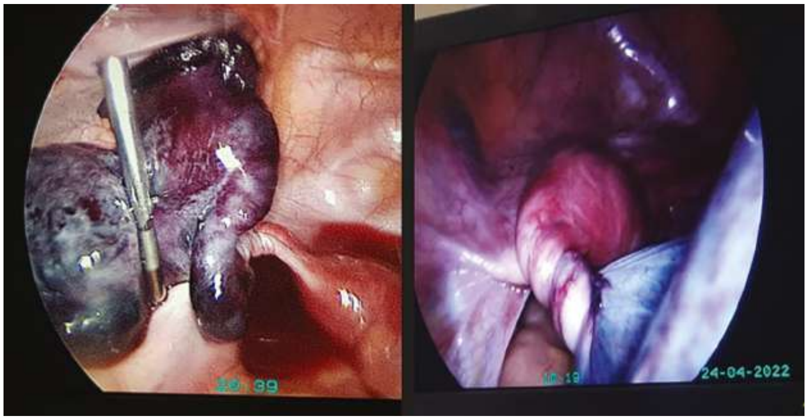
Caesarean (hysterotomy) scar pregnancy With increasing rates of caesarean section, scar ectopics are becoming more common. Options of treatment include medical management using systemic methotrexate as an intramuscular injection or injection of methotrexate or potassium chloride into the sac. Surgical management includes wedge resection of the pregnancy by laparoscopy or laparotomy.

CONDITIONS AFFECTING THE OVARY

OVARIAN CYSTS AND TUMOURS

Even with sophisticated preoperative imaging, the general surgeon will still occasionally operate, without a firm diagnosis, on a pelvic or abdominal mass and discover on entering the abdomen that the mass is ovarian. Similarly, a laparotomy for suspected peritonitis may reveal that the peritoneal irritation is from a complication of an ovarian cyst. Ovarian cysts are also not infrequently encountered by general surgeons as an incidental finding during the course of a laparotomy for some unrelated pathology. Gynaecological advice should be sought, but, if this is not available, then the general surgeon will require some knowledge of the pathophysiology of ovarian cysts and solid tumours in order to respond appropriately:

- *Physiological cysts* include single or multiple follicular cysts (which contain straw-coloured fluid) and corpus luteal cysts (which are associated with haemorrhage of varying degrees, either into the cyst or into the peritoneal cavity). Physiological cysts are seldom more than a few centimetres in diameter and do not need any intervention.
- *Endometriotic cysts* may be associated with other manifestations of endometriosis in the pelvis, and the ovary may be densely adherent to surrounding structures. Surface ‘chocolate staining’ is often absent, as these cysts have a thick capsule. Incision reveals single or multiple tense dark cysts, which contain altered blood.
- *Dermoid cysts*, a form of ovarian teratoma, are semi-solid. They can be single or bilateral and may involve the whole or only part of an ovary. They contain sebaceous material and can also contain any tissue, including teeth, hair and bone. They



26.8 Torsion of the ovary. ⏎

are usually an incidental finding unless they have undergone torsion or rupture. When the latter happens, the leaked material is irritant and may induce a chemical peritonitis.
- *Solid benign tumours* are easily misdiagnosed as malignant by a general surgeon. These may include fibromas, thecomas, cystadenofibromas and others. Ascites can occur with a benign fibroma and, when combined with a right hydrothorax, it is known as Meigs's syndrome, but it is comparatively rare.
- *Cystadenomas* are glandular cysts of the ovary. The serous cystadenoma contains straw-coloured fluid and the mucinous cystadenoma contains mucin. These cysts may be single or bilateral, unilocular or multilocular, and they may grow to a large size.
- With regards to *cystadenocarcinomas*, malignancy should be suspected if there are solid areas within the cyst or if there are surface papillomatous excrescences either on the serosal surface or on the cyst lining. General metastatic seeding on peritoneal surfaces, including the greater omentum, and the presence of ascites may make the diagnosis of malignancy more certain.

Complications of ovarian cysts

Haemorrhage, rupture, torsion or infection can occur with any ovarian cyst and it is these complications that commonly bring the cyst to the attention of the surgeon. The complication is treated and the cyst is then managed on its merits:

- *Haemorrhage* may be into a cyst, with resultant tension and pain, or into the peritoneal cavity. Active bleeding from an otherwise harmless cyst may be treated with diathermy coagulation or haemostatic sutures.
- *Rupture* of a cyst evokes a chemical peritonitis of varying severity, and the torn edges may bleed.
- *Torsion* of a normal ovary can occur (Figure 26.8), but it is more common when there is an ovarian mass. The torsion may be partial, with an engorged but viable ovary, or of several turns with complete vascular occlusion and rapid infarction. The Fallopian tube and ovary undergo torsion as a single unit and the pedicle thus formed can be simply clamped, divided and ligated if the ovary and tube are infarcted and require excision. In a partial torsion, untwisting may reveal a viable ovary that can be preserved.
- *Infection* is almost always secondary to another intraperitoneal infection. The cyst contents form an abscess, which must be drained.

Surgical options

When a surgeon encounters a small physiological cyst in a premenopausal woman, no treatment is required. Ovarian function should not be sacrificed in premenopausal women without good evidence of the necessity of sacrificing all or part of the ovary:

- An *ovarian cystectomy* preserves the ovarian tissue, even of the affected ovary. It is an appropriate operation for small, clinically benign cysts in a premenopausal ovary.[19]
- A *unilateral oophorectomy* preserves the function of the contralateral ovary. It may be the more appropriate treatment of a larger benign cyst, where little functioning ovarian tissue remains, and is also the recommended treatment of a benign solid tumour of a premenopausal ovary.[19] If, however, the contralateral ovary is absent or there is bilateral pathology, as is often the case in dermoid tumours, an ovarian cystectomy must always be considered.
- In the postmenopausal patient, a *bilateral oophorectomy* is usually recommended, even for an apparently benign cyst.[20]

Occasionally, the surgeon strongly suspects that an ovarian tumour may be malignant. The standard surgical treatment of an ovarian primary cancer confined to the ovary is a total hysterectomy with a bilateral salpingo-oophorectomy, infracolic omentectomy and retroperitoneal lymphadenectomy, which can be carried out depending on the possible cell of origin of ovarian cancer. This wide excision gives the best chance of total surgical removal of any visible and microscopic malignant spread and provides staging and prognostic information that will influence subsequent treatment. However, the general surgeon will not be operating with a preoperative diagnosis of ovarian cancer and, although the ovary may appear malignant, there is no histological proof. There should be a reluctance to proceed with a major resection in the speciality field of another surgical discipline. In an apparent solid ovarian mass, when the histology is finally reported as benign, such a major operation will be found to have been unnecessary. Patients are often dissatisfied in such situations due to a lack of adequate preoperative discussion and informed consent. For all of these reasons, a unilateral salpingo-oophorectomy without surgical spill is the best strategy for the general surgeon faced with this situation. Complete removal without spillage and peritoneal contamination is extremely important. If malignancy is confirmed and further surgery indicated, it can be completed at a second procedure.

More frequently, in epithelial ovarian cancer, the tumour is found to have already disseminated intraperitoneally at the time of laparotomy. A total hysterectomy, bilateral salpingo-oophorectomy, omentectomy, removal of involved peritoneum and grossly enlarged nodes, aiming at complete tumour cytoreduction, are indicated as a debulking procedure, as chemotherapy is more effective on small-volume disease. Although ovarian cancer responds to chemotherapy, recurrences are common and complete cytoreduction without residual disease is the only modifiable prognostic factor. There is resounding evidence that patients with ovarian cancer, when managed by gynaecological oncologists, have superior survival advantage. Depending on the patient's performance status, comorbidities, ability to withstand long cytoreductive surgeries, extent of cytoreduction required and possibility of achieving complete cytoreduction, patients are triaged, and neoadjuvant chemotherapy followed by interval cytoreduction can also be considered in those who are ineligible for primary cytoreductive surgery. Hence, it is prudent to consider early, prompt preoperative referral to gynaecological oncologists. However, in unexpected intraoperative predicaments, it is best that the general surgeon documents findings and takes a generous biopsy of the involved omentum for histological confirmation. The patient can then be transferred to a gynae-oncology centre for optimal further management. In an age when individualised cancer management with advanced procedures such as heated intraperitoneal chemotherapy (HIPEC) are available for ovarian tumours, elective gynaecological cancer surgery should be attempted by general surgeons only in very specific situations.

In very advanced disease, the patient can present to a surgeon with an intestinal obstruction, the aetiology of which is obscure until the abdomen is opened. Disseminated malignancy and malignant adhesions are encountered and the primary lesion is thought probably to be ovarian. Small bowel obstructions can be bypassed, but a large bowel obstruction in the pelvis most often necessitates a proximal loop colostomy. If an omental biopsy confirms disseminated ovarian malignancy, chemotherapy will usually offer palliation.

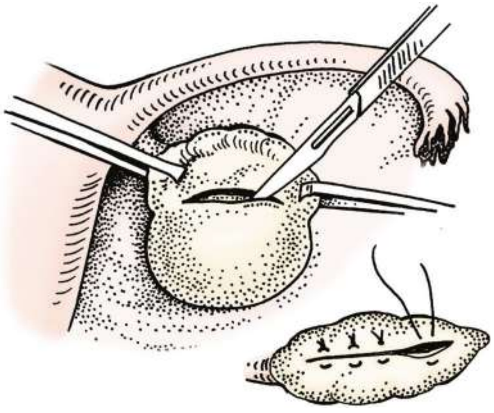
The surgeon must remember that malignant ovarian tumours may also be secondary to another primary malignancy, which are often larger and more apparent than the primary tumour, and they may occur either with, or without, other evidence of intraperitoneal seeding. *Pseudomyxoma peritonei syndrome* and *disseminated mucus-producing gastrointestinal adenocarcinoma* of appendiceal origin can produce a clinical picture identical to that of a disseminated ovarian primary. In either pathology, there may be extensive intraperitoneal disease or the pathology may appear initially to be confined to an ovary. If pseudomyxoma peritonei is confirmed histologically, the patient should be referred to a specialist centre; subsequent surgery in the pelvis will be more hazardous if an initial hysterectomy has been performed (see Chapter 14). Secondary (Krukenberg) tumours in the ovaries from gastrointestinal or breast malignancy may be large and cause symptoms. There may be no other macroscopic metastatic spread and the benefit of oophorectomy must be discussed with the primary oncologist prior to surgery. This is also discussed further in Chapter 14.

OVARIAN SURGERY

Surgery on the ovary is generally straightforward unless an ovary is found to be densely adherent to adjacent structures or is lying retroperitoneally. Most ovarian procedures are better performed laparoscopically.

Ovarian cystectomy

An incision is made through the ovarian cortex around the base of the cyst, deep enough to expose a plane of cleavage, which is developed by sharp or blunt dissection so that the cyst can be enucleated (Figure 26.9). After haemostasis, the ovary can be closed with



26.9 Ovarian cystectomy. The cyst is shelled out through an incision around the base of the cyst. A sutured repair of the ovary is shown in the inset. ⏎

an absorbable suture, taking care to abolish any dead space, which may fill with blood.

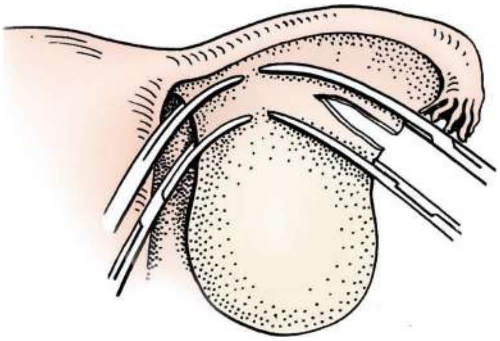
Oophorectomy

Oophorectomy requires the division between clamps and subsequent ligation of the infundibulopelvic ligament to secure the ovarian vessels (Figure 26.10). Separate ligation of the ovarian ligament may also be necessary.

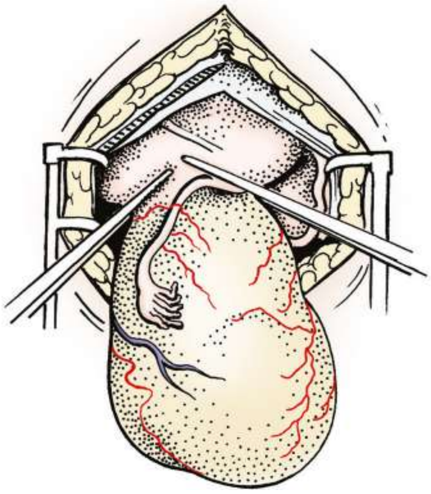
Salpingo-oophorectomy

Salpingo-oophorectomy is often the better option in a large cyst with the Fallopian tube stretched over its surface (Figure 26.11). A large serous cystoma can be drained down to a more manageable size before removal. A needle, attached to low-pressure suction, is passed through a purse-string suture placed in the cyst wall. It is important to isolate the area with packs and to minimise any spillage during aspiration. The needle is then withdrawn, the defect is closed with the purse-string suture and the cyst or ovary is removed. This manoeuvre will enable the surgeon to remove the cyst through a smaller abdominal incision. However, the surgeon must remember that a large cyst, especially in a postmenopausal woman, may ultimately prove to be malignant. If malignancy is a possibility, aspiration is contraindicated, as it is vitally important that there is no contamination of the peritoneal cavity with malignant cells. Instead, the abdominal wound must be enlarged to allow adequate access for gentle delivery of the cyst and identification of its pedicle. During a laparoscopic procedure, if drainage is attempted, complete evacuation of the cyst and closure of the puncture site with an endoscopic clip or suture is advised.

The lateral part of the pedicle is formed by the infundibulopelvic ligament containing the ovarian vessels, which, in the case of a large cyst, are likely to be much dilated. The medial or uterine part of the pedicle contains the Fallopian tube and the ovarian ligament. Separate clamps are placed on the two parts of the pedicle. Care must be taken to avoid inclusion of the ureter in the clamps on the lateral pedicle. It is advised that two proximal clamps and a transfixion ligature should be employed on the lateral pedicle because, if a clamp or ligature slips, the cut ovarian vessels may retract behind the peritoneum. Haemorrhage may be profuse and the cut ends difficult to identify.



26.10 Oophorectomy. The infundibulopelvic fold and the ovarian ligament are divided between clamps. ⏎



26.11 Salpingo-oophorectomy. The lateral pedicle clamp is on the infundibulopelvic fold containing the ovarian vessels. On the uterine side, the clamp is across the ovarian ligament and the proximal Fallopian tube. ⏎

Excision of retroperitoneal ovarian cysts

Excision of retroperitoneal ovarian cysts may be challenging. They tend to form when the cyst develops in the presence of surface adhesions and are not uncommon after a previous hysterectomy. These cysts are rarely malignant and seldom contain glandular tissue. The best approach is to open the peritoneum over the surface of the cyst, between the round ligament and the Fallopian tube, which are usually both stretched over it. A plane of cleavage is sought and developed digitally. The vascular pedicles should not be clamped until the ureter has been identified, as it lies in close proximity to the posterior surface of the cyst. Electrocautery and other energy devices must be used with caution and strictly under vision in these areas.

CONDITIONS AFFECTING THE UTERUS

General surgical practice is less commonly affected by uterine pathology than tubo-ovarian pathology. However, an enlarged fibroid uterus may obscure surgical access to the pelvis and an advanced tumour of the uterine body or cervix may invade the bowel.

ENDOMETRIOSIS

This gynaecological condition of ectopic endometrial tissue may have an impact on general surgical practice. The most common variety is of pelvic peritoneal nodules, which cause pelvic pain, and a laparotomy may have been performed by a general surgeon for some other suspected pathology. Early lesions are dark brown or purplish nodules a few millimetres in diameter, but later puckering and scarring of the peritoneum are more prevalent. Dense adhesions may form around the Fallopian tubes and, in severe cases, adhesions obliterate the rectovaginal pouch, involving the anterior rectal wall in the scar tissue. When encountered unexpectedly by the general surgeon, no surgical action is required. The overall management of endometriosis is complex, and any surgery that is indicated is supported, and complemented, by hormone manipulation.

Rarer forms of the disease are often only diagnosed after excision. A small bowel loop may be strictured by the scarring from a nodule of endometriosis on its wall. A sigmoid or rectal wall lesion may present with a stricture or with ulceration into the lumen and haemorrhage. A tender lump within a caesarean section scar, explored as a possible incisional hernia, will sometimes prove to be ectopic endometrial tissue.

HYSTERECTOMY

The general surgeon may have to remove the uterus *en bloc* with a rectal or sigmoid colon cancer that is invading the cervix or body of the uterus, and the hysterectomy is combined with a radical colonic or rectal resection. A similar challenge is posed by a locally advanced gynaecological cancer invading the rectum. These operations should ideally be performed as a combined procedure involving both specialists, but a colorectal surgeon will find that the additional dissection necessary for the hysterectomy is often relatively minor in this situation. In addition, the standard steps described in a hysterectomy must be modified so that the dissection does not breach the area of tumour invasion between the two organs. Occasionally, although the hysterectomy is not required for oncological reasons, pelvic access is restricted by a bulky fibroid uterus, and a hysterectomy has to be performed to allow a safe rectal dissection. Rarely, a general surgeon working in a hospital without gynaecological colleagues may have to perform an emergency hysterectomy for obstetric haemorrhage.

Total and subtotal hysterectomy are described in this chapter, but vaginal hysterectomy and the extended Wertheim hysterectomy for carcinoma of the cervix are outside the scope of a general surgical operative text. In a total hysterectomy, the whole of the uterus, including the cervix, is removed. A subtotal hysterectomy removes the body of the uterus but leaves the cervix. Carcinoma of the cervical stump is uncommon, but the patient should be advised to continue with cervical smears if smear test facilities are available. The subtotal operation is quicker and easier to perform, with a faster recovery and lower mortality and morbidity. It should always be considered in benign disease when there is poor access to the cervix due to obesity, fibroids or adhesions or when the patient's condition precludes a more prolonged procedure.

In both a total and a subtotal hysterectomy, conservation of the ovaries is preferable in the premenopausal woman. In a postmenopausal woman, elective oophorectomy may be beneficial. Oophorectomy may be offered to women over 50 years of age who place high priority on breast and ovarian cancer prevention. Opportunistic salpingectomy may be offered to women undergoing hysterectomy for benign conditions, as it results in decreased risks of epithelial cancer in the Fallopian tube, ovary and peritoneum in the average patient.

Total hysterectomy

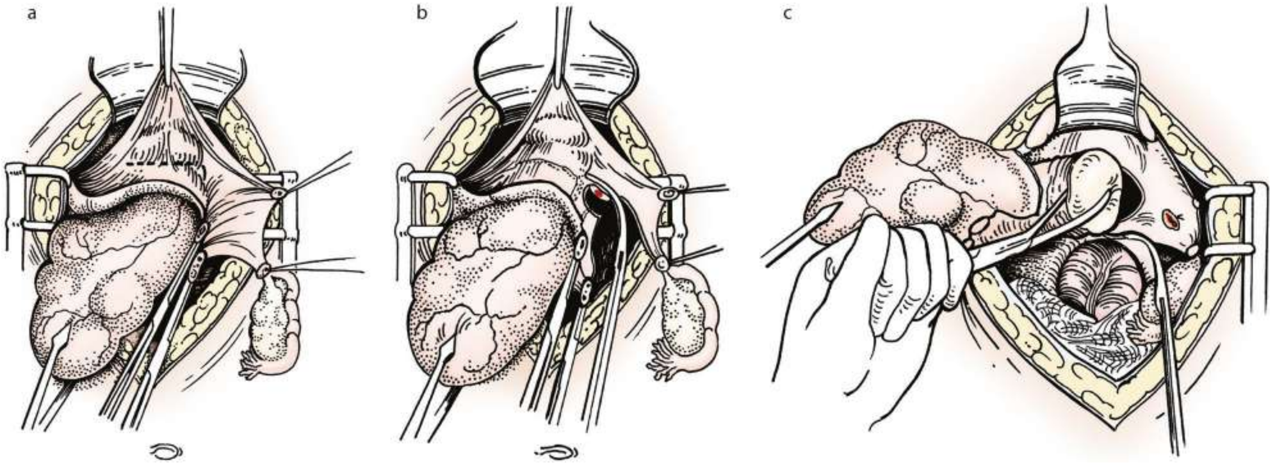
In situations in which a general surgeon is involved, the abdomen will normally already have been opened through a midline incision. However, a Pfannenstiel incision also provides good access for a hysterectomy. All pelvic surgery is easier with the patient positioned head-down and the small bowel held out of the pelvis with packs. A general surgeon will probably choose first to identify the ureters in familiar territory above the pelvic brim and to follow them distally before embarking on any pelvic dissection.

The uterus is elevated and a clamp, such as a Jessop, Ochsner or Kocher, is placed across each cornu, incorporating the round ligament, the ovarian ligament and the Fallopian tube. The tip of each clamp is angled laterally into an avascular 'window' in the broad ligament. Further clamps are applied alongside, and parallel to, the first, and the tissue is divided between them. The pedicles are transfixed and ligated. The original cornual clamps remain in place and are used to retract the uterus. If the ovaries and tubes are to be removed, the round ligament is clamped lateral to where it separates from the Fallopian tube, and the infundibulopelvic ligament containing the ovarian vessels must also be secured as already described in the section on salpingo-oophorectomy.

Development of the space between the leaves of the broad ligament by finger dissection can be helpful at this stage. The peritoneal incision in the anterior leaf of the broad ligament is then carried downwards close to the uterus, towards the base of the ligament, and is then continued towards the midline across the uterovesical pouch at the junction between the uterus and cervix where the peritoneum is loosely attached (Figure 26.12a). The anterior flap of peritoneum is raised to expose the bladder. The fascial strands between the cervix and bladder are divided to open a plane of cleavage. The bladder, with the lower half of the vesicouterine fold of peritoneum, is now pushed down off the cervix and the upper part of the vagina. This carries the ureter downwards with the bladder to below the level of the uterine artery, and should safeguard it when the vessel is clamped. Caudal retraction of the bladder and anterocranial traction on the fundus help to move the ureters away from the pedicle clamps. More laterally, stripping must be done gently, as parametrial venous plexuses may be torn. When the cervix is long or there is scarring from a previous caesarean section, it may be necessary to leave the final dissection of the bladder off the cervix and vaginal vault until the uterine vessel pedicles have been divided.

The uterine vascular pedicle is secured with a clamp, angled at almost 90° to the cervix, with the tip on the cervix itself so that, when the clamp is closed, the tip slips off to grip tissue as close to the cervix as possible. A second clamp is applied, parallel to the first, the uterine vessels are divided and then they are transfixed and ligated (Figure 26.12b).

Any further dissection to expose the vagina is completed and the vagina is opened transversely, with scalpel or diathermy, in the midline anteriorly until a vulsellum retractor can be placed on the anterior lip of the cervix (Figure 26.12c). Combined upwards traction on the vulsellum and the cornual clamps places the lateral vaginal angle on tension. An angled Kocher clamp is applied to incorporate the lateral vaginal angle, the descending cervical branch of the uterine artery and the uterosacral ligament posteriorly. The uterosacral ligament may need to be taken separately if it is thickened because of endometriosis or chronic inflammation. Releasing the uterosacral ligaments usually results in the uterus becoming more mobile and may aid the surgery. The circumferential vaginal incision is completed posteriorly and the uterus is removed.



26.12 Hysterectomy. (a) The right Fallopian tube and round ligament have been clamped separately in this illustration. The laterally placed clamps have been tied off and the medial clamps retained as retractors. The uterovesical peritoneal fold has been elevated and the planned incision is shown. (b) The bladder has been displaced downwards off the cervix. The uterine vessels are then clamped close to the uterine wall. (c) The vagina is opened and a vulsellum retractor is placed on the cervix for retraction while the vaginal division is completed. ⏎

In situations in which there is a malignancy invading across the rectovaginal pouch, the posterior incision through the vaginal wall must be well below any tumour invasion, and access will have to be from the sides. The excised tumour specimen may then include a major portion of the posterior vaginal wall.

Each vaginal angle is undersewn by an over-and-over suture, starting at the tip of the clamp and working laterally. It incorporates the vagina at the front and back, with the last pass being under the heel of the clamp. The clamp is removed and the suture is drawn tight and tied. The vagina is then closed with a continuous haemostatic suture. If there is concern over haemostasis, the vaginal edge should be oversewn to leave a central aperture through which a wide T-tube drain can be placed. Hitching the vaginal vault to the stump of the uterosacral ligament could help to reduce the risk of vault prolapse. There is no need to close the pelvic peritoneum.

If the operation is performed laparoscopically, the same steps should be followed with the pedicles either ligated intracorporeally or sealed with a vessel-sealing device. After dividing the uterine arteries, the operation can be continued laparoscopically or, alternatively, the cervix can be pulled down into the vagina and the remaining steps completed vaginally. Care must be taken to ensure separation of the bladder from the cervix before the peritoneal cavity is entered. It is safer to enter the peritoneum posteriorly and then open the vesicovaginal fold after defining the extent of the bladder.

Subtotal hysterectomy

The operation is performed as for a total hysterectomy up to, and including, ligation of the uterine vascular pedicles. The dissection is not then carried so deeply into the pelvis and the bladder is not separated from the vaginal vault. The cervix is divided through its extravaginal portion and oversewn with absorbable sutures. This closure can be improved if the two halves of the cervix are cut into a V-shaped wedge.

Postpartum hysterectomy

Very occasionally, a general surgeon may be required to carry out this operation for uncontrollable haemorrhage. Generally, the tissue planes are well developed and the enlarged blood vessels easy to identify. However, identifying the limits of the dilated cervix may be difficult and can lead to incomplete removal. The surgeon unfamiliar with total abdominal hysterectomy would be wise to consider the subtotal operation. A hysterectomy must occasionally be combined with a caesarean section. Closure of the uterine caesarean incision before embarking on the hysterectomy is recommended to reduce haemorrhage.

SURGERY IN PREGNANCY

Any surgical pathology may present in pregnancy. Surgery in the first trimester is complicated by concerns regarding the possible teratogenic effects of anaesthetic drugs and any abortifacient effect of the condition requiring surgery, or of the surgery itself. Elective surgery should therefore be avoided during this period. However, as intraperitoneal sepsis is a more powerful factor than intra-abdominal surgery in inducing a miscarriage, the surgeon should not err on the side of conservative management when, for example, appendicitis is suspected.

In the mid trimester, the chances of miscarriage are low, the risk of major teratogenic effects has passed and the uterus is not yet obscuring access. This is therefore the optimum period to operate if postponement of surgery until after delivery appears unwise. Diagnosis of abdominal conditions in late pregnancy can be difficult, as the uterus is in contact with most of the anterior abdominal wall, masking physical signs from gastrointestinal pathology, and all the abdominal organs are displaced cranially from their normal anatomical sites. Access for surgery is difficult and, in addition, the patient lying supine will often obstruct her venous return by the weight of the gravid uterus on the inferior vena cava. The surgeon will thus have to operate with the patient tilted, usually into a partial left lateral position. Close to term, a laparotomy for surgical pathology may sometimes be best combined with a caesarean delivery.

Avoidance of radiation to the fetus is important throughout pregnancy, and surgery may be hampered by the lack of preoperative or intraoperative imaging. Ultrasound and magnetic resonance imaging (MRI) can be safely used in pregnancy.

The life-threatening emergencies associated with pregnancy itself, and which require urgent surgical intervention, will involve a general surgeon only if no gynaecologist is available. Ectopic pregnancy was discussed earlier in this chapter.

RESCUE CERVICAL CERCLAGE TO MAINTAIN A PREGNANCY

Cerclage is performed to reduce pregnancy loss or preterm birth in women at risk based on their previous history, ultrasound examination or a dilated, shortened cervix on per vaginal examination.[21] Most cerclages are placed between 12 and 24 weeks of gestation.

When the cervical os is open on vaginal examination, a rescue cerclage should be performed. If there are prolapsed membranes, these should be replaced, as there is an increased chance of rupture of membranes. The membranes may be replaced by a steep Trendelenburg position, administering a uterine relaxant and backfilling the bladder. An inflated bladder catheter in the cervix may be used to push the membranes back while the cervical suture is being tightened.

The type of suture used commonly is the McDonald suture, which is a purse-string suture that is placed as close to the internal os as possible. There is no dissection involved. A monofilament suture is preferred, and the knot may be placed anteriorly or posteriorly depending on the operator's convenience.

A Shirodkar stitch is more complicated in that it involves dissection of the bladder off the anterior cervix, and the rectum off the posterior cervix, in order to identify and place the suture at the internal os. Two atraumatic needles premounted with 5 mm Mersilene tape are used. This stitch is typically used when a prior McDonald stitch has failed.

EMERGENCY CAESAREAN SECTION

Operative intervention to deliver a baby may be urgently required when severe fetal distress indicates that the life of the baby is threatened from whatever cause. There is also urgency to deliver a stillbirth when the life of the mother is threatened by eclampsia or by haemorrhage. Neither eclampsia nor haemorrhage can be controlled until the uterus is emptied. Intervention with less urgency may be required during a labour that fails to progress whether for mechanical or for physiological reasons.

In the emergency situation, a caesarean section is necessary if imminent vaginal delivery cannot be achieved. Assisted vaginal delivery by forceps or vacuum extraction is often preferable if the head is engaged in the pelvis and the cervix is fully dilated. Destructive procedures, such as craniotomy and cleidotomy, may be considered in a case with a dead fetus.

Today, an emergency caesarean section virtually always utilises a lower segment incision rather than the classical procedure. In a classical caesarean section, the upper segment of the uterus is opened through a vertical incision and the fetus is delivered as a breech. In the lower segment operation, the lower uterine segment is incised transversely and the fetus is delivered head first if the vertex is presenting. A lower midline incision in the abdominal wall can be used for both, but the transverse Pfannenstiel approach or the slightly higher Joel-Cohen incision (which is quicker to perform) is favoured for most lower segment operations.

Lower segment caesarean section

A lower segment caesarean section can be performed under general, spinal, epidural or even local infiltrative anaesthesia. A general anaesthetic in labour, without adequate airway protection, carries a high risk of inhalation of gastric contents. In addition, anaesthetic drugs will cross the placenta and may depress the baby's respiratory efforts after delivery. Regional anaesthesia may therefore be safer if anaesthetic skills are limited. The mother should be catheterised and placed with a 10–15° left lateral tilt to prevent pressure of the uterus on the vena cava.

Operative procedure Whichever incision is chosen, it must be long enough to accommodate the fetal head with a hand alongside the head. Care must be taken on opening the peritoneum to avoid injury to the bladder. The uterus is then checked for rotation, which is virtually always to the right. If wet packs are used to isolate the uterus from the rest of the peritoneal cavity, a pack placed first on the right side may help to correct this rotation.

The lower segment is identified as the area beneath the vesicouterine reflection of peritoneum where the peritoneum lies free of the uterine wall. This fold of peritoneum is picked up and incised transversely almost as far as the broad ligament. The lower half, with the bladder attached, is then pushed down to expose the lower segment. There may be dilated veins overlying the lower segment. These can be oversewn or merely kept compressed by an assistant while the lower segment is opened. A Doyen, or similar, retractor is used to hold the bladder and peritoneum down and out of the way. New studies suggest not raising the bladder flap and cutting directly through the visceral peritoneum after visually ensuring the bladder is away from the operative site.[22]

A 3–4 cm transverse incision is made in the uterine muscle, high in the lower segment, and deepened until the membranes bulge, which they will do if amniotic fluid is still present in quantity. It does not matter if the membranes are opened at the initial incision, but there is greater control if this is done as a separate layer. Too low an incision in the lower segment must be avoided, as it may not be possible to create a long enough incision in this narrower portion to deliver the fetus, and tearing can occur either down into the cervix or laterally into the uterine vessels or ureter. The lower uterine segment may be very thin after a prolonged labour, and care must be taken not to cut too deep and lacerate the fetus.

The incision is then extended laterally, preferably using fingers. Before labour is established, and particularly in a preterm pregnancy, the lower segment is poorly developed and there is a danger of entering the uterine arteries as the incision is carried laterally.

A 'smile'-shaped incision with the lateral extensions curved upwards may overcome this problem and is a better solution than the classical incision. It is wise to place a stay suture at the midpoint of the lower edge of the uterine incision so that it can be found more easily when closing the uterus.

The presenting part must now be delivered up from the pelvis. In a cephalic presentation, the surgeon slides the fingers of one hand down alongside the head to release the vacuum of a tight fit; there is more room over the face. The hand is then used as a 'scoop', or one forceps blade is used as a 'shoehorn', to draw the head up to the lower segment opening. Fundal pressure then assists delivery. The head should be allowed to deliver slowly and flexion should be maintained to reduce the diameter of the fetal head as it is drawn through the uterine incision.

A deeply impacted head may be difficult to deliver upwards, and an assistant pushing the head up from the vagina is helpful. A high, free-floating head can also pose difficulty and is easiest solved by using forceps or a ventouse device or by finding the anterior ankle, doing a podalic version and delivering the baby by breech extraction.

The baby is delivered and its airway is attended to by an assistant while the surgeon completes the operation. The umbilical cord is ligated, or clamped, and divided. Oxytocin is given to speed the natural contraction of the empty uterus and the separation of the placenta. Normal physiological separation of the placenta should then be awaited but, if delay occurs, gentle cord traction can be applied if the fundus is contracted. Meanwhile, brisk bleeding from the edges of the uterine incision can be controlled with non-crushing Green-Armytage or Rampley clamps. The placenta and membranes should be checked for completeness and the uterine cavity is checked digitally.

The uterine incision is then closed. A continuous haemostatic suture is satisfactory and should be started from both ends, as not only is haemorrhage most profuse from the lateral angles, but also access is most difficult. These initial lateral angle sutures can be placed before delivery of the placenta and will reduce blood loss. An absorbable material, such as 0 or 1 catgut or polyglactin, is suitable for uterine closure. A two-layered closure, burying the first layer, can be used if a single layer does not provide sufficient haemostasis. Beware of including the bladder in the stitch or of sewing the upper edge of the uterine incision to the posterior wall of the uterus. Any isolated bleeding points can be controlled by an additional interrupted suture. It was traditional to close the vesicouterine fold of peritoneum as a loose third layer, but this is now often omitted. The peritoneal cavity is cleared of liquor and blood, and the abdomen is closed.

Classical caesarean section

The classical vertical incision through the uterine body leaves a scar that is more liable to rupture in future pregnancies and should be avoided if possible. Indications for a classical incision may be absolute or relative, but include a mother who is dead although her baby is still alive, a cervical cancer, placenta accreta spectrum and a very premature pregnancy with a poorly defined lower segment. For babies with a large head or with gross fetal abnormalities, an inverted T- or J-shaped incision can be utilised.

The preparation of the patient is similar: the abdomen is opened through a lower midline incision and a midline vertical incision of at least 15 cm in length is made in the body of the uterus. A cephalic presentation is then delivered as a breech extraction. The management of the third stage and the uterine closure are similar to those described for a lower segment caesarean section.

SEVERE HAEMORRHAGE IN THE OBSTETRIC PATIENT

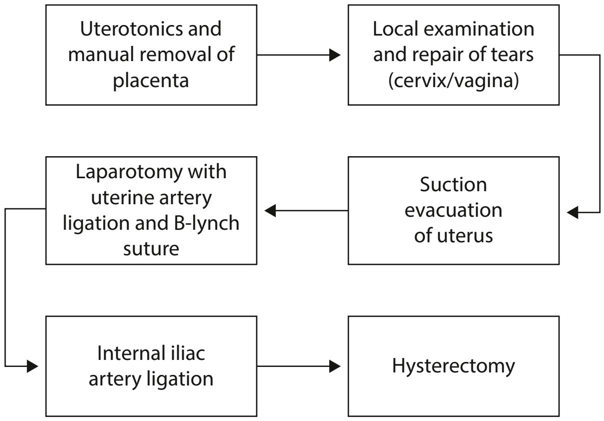
In all situations, maternal blood loss will continue unabated until the baby and the placenta have been delivered and the uterus can contract and close the open sinusoids. Retained products of conception, or even blood clot, can also prevent satisfactory uterine contraction. In patients who are actively bleeding post-miscarriage, a manual vacuum aspiration or a dilatation and curettage must be done.

Pre- and intrapartum haemorrhage

If the fetus is still *in utero*, it must be delivered immediately, and this will usually require a caesarean section. The most common causes for antepartum haemorrhage are abruption and placenta praevia. Active management of the third stage of labour is advised.[23] A retained placenta is also associated with haemorrhage, and the first priority, alongside resuscitation, is delivery of the placenta. A general surgeon is unlikely to be involved until after the standard manoeuvres of oxytocin administration, fundal rubbing and controlled cord traction have failed. Manual removal of the placenta is the next step and, if this fails due to a morbidly adherent placenta that intrudes through the uterine wall, an emergency hysterectomy may be required to control haemorrhage (Figure 26.13).

Uterine inversion

Uterine inversion, sometimes associated with a placenta that is still attached, presents with haemorrhage, profound shock that is out of proportion to the


Uterotonics and manual removal of placenta
Local examination and repair of tears (cervix/vagina)
Suction evacuation of uterus
Laparotomy with uterine artery ligation and B-lynch suture
Internal iliac artery ligation
Hysterectomy

26.13 Stepwise management of acute obstetric haemorrhage. Notes: Uterotonics include intravenous/intramuscular oxytocin, intravenous methylergometrine, intramuscular carboprost and per rectum misoprostol. For atonic postpartum haemorrhage, certain instruments have been described to clamp the uterine arteries vaginally. Strong suction within the uterine cavity has also been shown to reduce bleeding. During hysterectomy, care should be taken to keep the bladder away to prevent ureteric and bladder injury. During bilateral internal iliac artery ligation, it is safer to tie one side and occlude the other with a vessel loop. Following cessation of bleeding, the loop can be removed. If bleeding recurs, this should be tied off. ⏎

blood loss, and a mass within or outside the vagina. The uterus should be returned to its normal position as soon as possible, before the cervix contracts, necessitating a general anaesthetic for replacement. Reduction is achieved by manual manipulation within the vagina, and any attempt to remove a retained placenta is delayed until the uterus has been restored to its normal position. After reduction, and additional manual removal of the placenta if it is still attached, the surgeon's hand should remain inside the uterine cavity to prevent recurrence of the inversion, until the uterus starts to contract. A uterine inversion can also be reduced by hydrostatic pressure. Saline (2 L) is run into the posterior fornix from a height of 2 m, and both hands are used to hold the vagina closed and prevent fluid escape.

Postpartum haemorrhage

Resuscitation should run parallel with the assessment of the cause of haemorrhage. The abdomen is palpated and, if the uterus is found to be well contracted, the likely source is genital tract haemorrhage from trauma to the perineum, vagina or cervix. This should be explored and repaired. A *cervical laceration* can cause massive haemorrhage immediately after delivery and can usually be sutured *per vaginam*.

The vagina should be examined for lacerations and sutured carefully. If lacerations are deep, they are best examined under anaesthesia and repaired.

Occasionally, there may be extensions through the pouch of Douglas, and a laparoscopy or laparotomy may be necessary to assess the damage to adjacent organs.

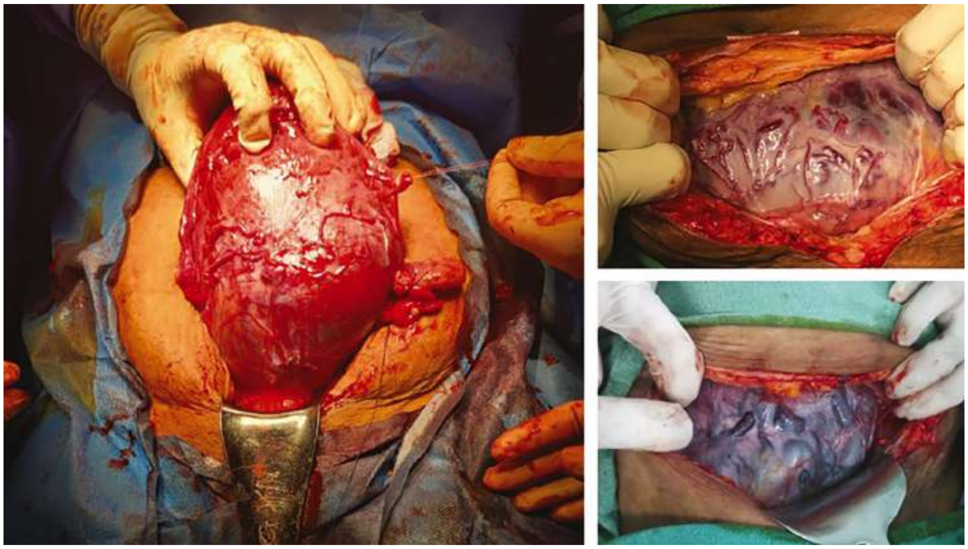
Haematomas can occur in either the vulva or the vagina. Small vulval haematomas may be managed conservatively with analgesia and ice packs. A urinary catheter may need to be placed, as severe pain may cause urinary retention.

If the vulval haematoma increases in size, there may be a need for surgical intervention. An incision is made to drain the haematoma and the bleeding vessels are ligated. The space created is washed out and re-approximated using figure-of-eight absorbable sutures. A drain may be left *in situ*.

Vaginal haematomas are also approached in a similar manner. Haematomas larger than 4 cm need to be drained. Haemostasis is achieved prior to approximating the mucosal edges. Vaginal packing may be helpful to achieve tamponade. If the patient becomes unstable, extension into the broad ligament or retroperitoneum needs to be considered, although is very rare.

If the uterus is not contracted, the standard obstetric manoeuvres of oxytocin and prostaglandin administration, fundal rubbing and even manual exploration of the uterine cavity to remove clot and retained membranes will almost always have been undertaken before a general surgeon is involved. Packing of the uterine cavity may have been tried, but is seldom helpful. Tamponade with a Bakri balloon, or alternatives such as a Sengstaken–Blakemore tube inflated up to 300 mL or a Rüsch balloon, may be a better temporary solution. In the absence of any of these devices, a surgical glove or condom tied with suture material to a plastic catheter may have the same effect. (A Foley catheter balloon can be used for a similar haemorrhage in early pregnancy.) The patient can then be fully resuscitated and clotting restored to normal. With haemorrhage continuing from an atonic empty uterus, the choices are embolisation, a brace suture to compress the uterus, uterine or internal artery ligation, or a hysterectomy.

With increasing rates of caesarean section, placenta accreta spectrum (PAS) disorders are on the rise (Figure 26.14). These are better managed in tertiary care centres with multidisciplinary teams involved. Women with PAS disorders often require massive transfusions. If PAS is not diagnosed antenatally, telltale signs of the placenta eroding into the myometrium – including loss of the plane between the endometrium and placenta on ultrasound with lakes of fluid noted and large blood vessels covering the uterine surface in the areas of placental erosion



26.14 Placenta accreta spectrum. ⏎

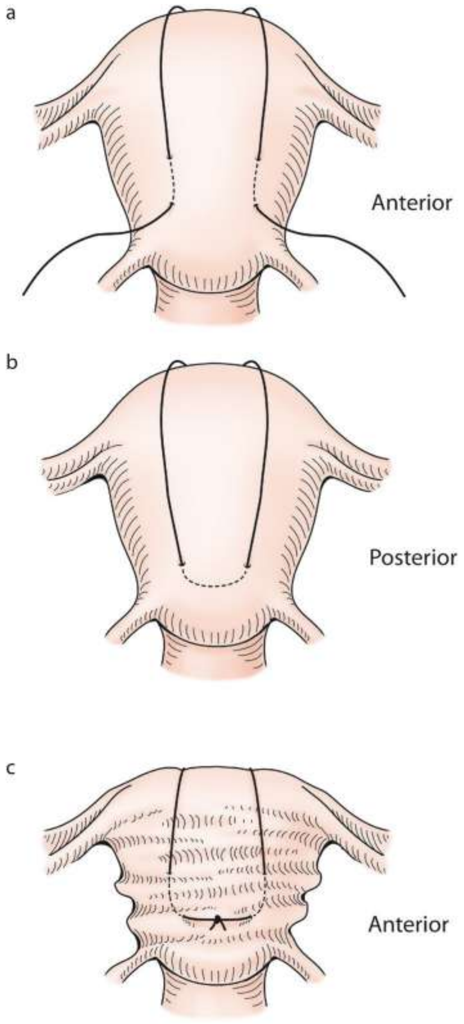
– should alert the surgeon to the risk of placenta accreta. Sometimes, the uterine wall itself is made up of the placenta. In these situations, it is *imperative not to disturb the placenta*. Since the placenta is usually implanted in the lower segment, a classical caesarean section must be carried out and the baby extracted without removing the placenta.[24] With the placenta remaining *in situ*, the uterine incision should be closed and a caesarean hysterectomy carried out. Attempts at placenta removal are often met with profuse haemorrhage.

B-Lynch brace suture

This ingenious compression suture, first described in 1997, is now a recognised technique.[3,25] The patient is anaesthetised in a semi-lithotomy position so that the rate of bleeding *per vaginam* can be monitored. The abdomen is opened and the uterus lifted out of the abdominal cavity and manually compressed. If this manoeuvre successfully stems the haemorrhage, the suture is worth trying. The vesicouterine peritoneal fold is divided in the same way as for a caesarean section and the lower segment is exposed. A heavy absorbable suture (originally described with No 2 chromic catgut) on a large round-bodied needle is required. The needle is passed from below upwards, entering the right side of the uterus 3 cm below the limit of the lower segment and 3 cm from the lateral border. The suture is brought out 3 cm above the limit of the lower segment and 4 cm from the lateral border. The stitch is then taken up and over the compressed fundus, 3–4 cm from the right cornual border. The suture is then carried down and enters the posterior wall of the uterus opposite and at the same level as the upper entry point at the front, and is carried through and around to emerge at the same level on the left posterior surface. It is then carried up the back and over the fundus 3–4 cm from the left cornual border, down the front of the uterus to enter 3 cm above the lower segment and emerges 3 cm below at the same distance as on the right side (Figure 26.15a, b). The two ends are then pulled tight, with an assistant compressing the uterus bimanually, and tied (Figure 26.15c). The original description of this procedure recommends that the lower segment is opened. However, surgeons using this technique have not always found this step necessary for success. If the lower segment has been opened, it is then closed in a similar manner to that after a lower segment caesarean section.

Internal iliac artery ligation

About 50% of emergency hysterectomies for haemorrhage can be prevented by using this technique. However, it is not an easy operation and the surgeon must remember that the first priority is to save the life of the woman, and this must not be further jeopardised by futile attempts to save her uterus. A uterine rupture or cervical laceration that extends out into a uterine vessel can cause major haemorrhage, which cannot be controlled, as the torn ends of the uterine vessel cannot be safely secured. Blind sutures risk injury to the ureter. Ligation of the internal iliac artery (Figure 26.16), ideally its anterior division that supplies the viscera, on the side of the haemorrhage is often effective.[26] However, there is an extensive collateral blood supply to the pregnant uterus, and even bilateral internal iliac artery ligation may occasionally not stem a postpartum haemorrhage, whether from an atonic uterus or from obstetric trauma. This is a



26.15 B-Lynch brace suture. (a, b) The position of the suture, viewed from in front and behind, before it is tightened. (c) The suture is tightened, compressing the uterus and its arterial inflow. ⏎

similar situation to that encountered in major pelvic fractures, where the haemorrhage is more satisfactorily controlled by embolisation (see Chapter 17). Bilateral ligation of the posterior branch that supplies the gluteus and perineum carries the theoretical risk of perineal skin necrosis. In situations of torrential bleeding, it is advisable to tie one artery and occlude the other with a vessel loop, complete the hysterectomy and then release the loop and watch for bleeding. If bleeding cannot be controlled, then the artery can be tied.

Ruptured uterus

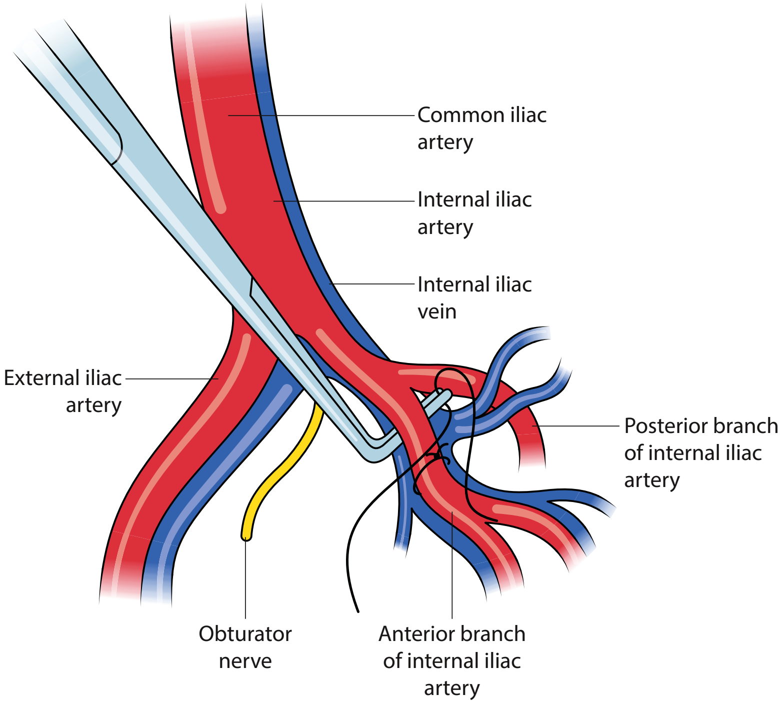
In previous decades, the prevalent cause for ruptured uterus was unattended obstructed labour. However, with the advent of increasing deliveries by caesarean section, in recent years ruptures are mainly due to weak caesarean scars. Generally, these ruptures happen along the line of the previous scar and, hence, although the baby is not usually salvageable, the uterus can be closed like a caesarean section. However, occasionally, when the lower segment is very thin, the rupture can extend distally, tearing the uterus, even distally to the cervix. In this situation, the first step is to carefully dissect the bladder off the anterior lip of the cervix. The venous plexus in this region tends to bleed, which should be controlled by pressure or suture ligatures with 3/0 Vicryl. Electrocautery is best avoided in this area due to the proximity of the bladder. Once the bladder has been completely separated from the anterior uterine flap, the edges can be held with Green-Armytage forceps and the apex identified. A tear going down to the cervix needs to be sutured individually, followed by the lower segment incision, forming a T-shaped scar. Ideally, a tubal ligation should also be carried out.

Bladder rupture

Rarely, in a severe uterine rupture, the bladder can also be ruptured. Sometimes, in the case of previous caesarean sections, the bladder is stuck densely to the uterine scar and is opened during the dissection. This is not as disastrous as one would imagine, if the surgeon keeps in mind that the bladder will heal well if:

- Re-suturing is carried out with adequate thickness of the detrusor muscle
- The urinary catheter is kept patent without any kink or blockage
- The bladder is kept as dry as possible in the initial period

Ideally, both ureters should be stented first with 5 Fr infant feeding tubes and the ureteric catheters exteriorised through the anterior abdominal wall, or per urethra using a cystoscope. A large calibre suprapubic catheter is placed through a virgin site on the anterior bladder wall and a large bore Foley catheter per urethra. The bladder is then closed with two layers of continuous sutures using 3/0 polyglactin or 3/0 PDS. The first layer takes the muscularis and submucosa with, or without, the mucosa and the second layer incorporates the serosa, burying the first layer. A drain must be placed in the pouch of Douglas. Some surgeons do not use a suprapubic catheter, in which case the urethral Foley catheter should be watched closely so that sediment or blood clots do not block the catheter. The urethral Foley catheter can be removed in 2–3 weeks once a leak is ruled out. If a suprapubic catheter has been used, it can be clamped and removed if the patient is voiding satisfactorily.



26.16 Internal iliac artery ligation. ⏎

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27 Paediatric surgery for the general surgeon

Dhruva Ghosh, Nitin James Peters and Tanvi Goel

LEARNING OBJECTIVES

- Understand the operative approach to common neonatal and paediatric surgical disorders
- Learn about the common paediatric operations for the general surgeon
- Be familiar with the management of perioperative fluid and electrolyte resuscitation in children
- Understand the differences in the surgical anatomy between children and adults
- Understand the surgical principles of paediatric surgery

INTRODUCTION

The oft-repeated adage 'Children are not small adults' is the sentinel feature in the surgical management of children. The age spectrum from a neonate to 18 years encompasses a wide spectrum of physiological and anatomical variations. These changes require significantly different approaches in perioperative management, anaesthesia, surgical principles and postoperative care across the different age groups.

In most middle- and high-income nations, the specific disease groups are increasingly managed by specialised surgeons (e.g. cleft lip and palate by plastic surgeons). However, many paediatric surgical diseases from head to toe, including paediatric orthopaedics, are frequently managed by general paediatric surgeons or the general surgeon with a keen interest in paediatrics. In many parts of the world, the onus of managing common paediatric surgical conditions may fall on the general surgeon due to the paucity of paediatric surgeons.

In this chapter, we will cover common conditions that may be encountered by the general surgeon and consider the perioperative and operative approaches. The full range of paediatric surgery is, of course, very extensive and not possible to cover in a single chapter.

NEONATAL AND PAEDIATRIC PHYSIOLOGY

AGE

Different age subsets will have variable considerations with regard to their anatomy, physiology, pathology, pharmacology and approach to surgery. Neonates are defined as babies under 4 weeks and infants are defined as children under 1 year. Various countries and hospitals may have an arbitrary age cut-off to define the upper age limit of paediatrics (13, 16 or even 18 years).

Adolescents are between 10 and 19 years and young adults are between 20 and 24 years. Surgical management should be performed by surgeons who are well informed, and preferably have some training and experience, in paediatric surgery. Ideally, there should be a robust system of transitional care from paediatrics to adult surgical practice.

PERIOPERATIVE FLUID RESUSCITATION IN CHILDREN

The total body water (TBW) in terms of body surface area is significantly higher in neonates, especially preterm neonates. A neonate, at term, would have approximately 80% TBW. After birth, the TBW rapidly declines and reaches the adult levels of 60% by

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about 2 years of life. Postnatally, the extracellular component also rapidly decreases. Most fetal water unloading occurs in the first 2 weeks of life.

The syndrome of inappropriate antidiuretic hormone secretion (SIADH) is commonly seen in babies with surgical stress and systemic disorders such as sepsis. This syndrome includes hyponatraemia (Na+ < 135 mEq/L) with inappropriately concentrated urine in the clinical setting of normal volaemia (euvolaemia) or mild hypervolaemia.

Sodium maintains the intravascular volume through the antidiuretic hormone (ADH) mechanism. ADH is known to bind to receptors in the distal nephrons and results in water retention. The clinical relevance here is that hypotonic resuscitation may cause further hyponatraemia, eventually leading to physiological worsening including encephalopathy.

In the immediate postoperative period, fluid restriction should be the fundamental principle. In the case of a decrease in postoperative urine output, an adequate isotonic bolus must be administered to maintain the requisite sodium homeostasis. In cases of severe hyponatraemia (Na+ < 125 mEq/L), 3% NaCl should be used, keeping in mind the gradual Na+ correction strategy.

Fluid management in children undergoing surgery is different from that in adults. The four main headline topics include acute circulatory support, correction of losses, replacement of ongoing losses and maintenance fluid therapy. Before prescribing fluids, the normal range of physiological parameters must be kept in mind (Tables 27.1 and 27.2).

The assessment of dehydration is essential before administering fluid in children. Optimal fluid and electrolyte resuscitation is different in different age groups for surgical patients in the paediatric cohort (Table 27.3).

After administering the calculated volume for 4–6 hours, the patient needs to be reassessed by monitoring urine output and the clinical hydration status. In more challenging cases, biochemical factors such as serial serum and urinary osmolality, urinary and serum sodium, and creatinine and blood urea nitrogen levels should be evaluated and used as a guide for further fluid management. This should be repeated every 6–8 hours for neonates.

Correct estimation of fluid requirement depends upon pre-existing deficits or excesses, metabolic demands and ongoing losses. These are dynamic changes and require close monitoring of hydration status, fluid intake and urinary output. Early recognition of these imbalances should be picked up to maintain good homeostasis in the perioperative period.

Table 27.1 Vital signs in children ⏎

Age (years)	Heart rate (bpm)	Systolic blood pressure (mmHg)	Respiratory rate (breaths per minute)
<1	110–160	70–90	30–40
2–5	90–140	80–100	25–30
5–12	80–120	90–110	20–25

Systolic blood pressure = 80 + (age in years × 2) mmHg.

Table 27.2 Maintenance of fluid requirements ⏎

Age and weight	Daily fluid requirement	
	mL/kg/day	mL/kg/hour
Neonate	120–150	5
Child		
First 10 kg	100	4
Second 10 kg	50	2
Subsequent kg	20	1

Table 27.3 Assessment of dehydration in children ⏎

Severity of dehydration	% of dehydration: Infant	% of dehydration: Child	Symptoms
Mild	5	3–4	Thirst, external jugular vein visible in supine position, mucous membranes moist, capillary refilling time >2 seconds, urine specific gravity >1.020
Moderate	10	6–8	Dry mucous membranes, tachycardia, sunken fontanelle, decreased skin turgor, decreased urine output
Severe	15	10	Sunken eyes, cool peripheries, apathy, somnolence, orthostatic hypotension
Shock	>15	>10	Decompensation, poor tissue perfusion, hypotension, oliguria/anuria

GESTATION AND BIRTH WEIGHT

Neonates are a special group with distinct and dynamic physiology. The newborn adapts from the placental life, transitioning to neonatal physiology, and undergoes several rapid changes in early life, commencing from the first breath.

Neonates are categorised based on gestational age and weight. Term neonates are those born between 37 and 42 weeks of gestation. Any baby born before 37 weeks is defined as a preterm and a baby born after 42 weeks is a post-term neonate. Extreme prematurity (as early as 21 weeks' gestation) may be salvageable due to the advances in neonatal care. However, several ethical concerns loom over these clinical decisions and any further surgical care, as neurological function may be severely affected in the survivors.

Birth weight, along with gestation, is one of the most important determinants of neonatal survival and outcomes. Low birth weight is defined as a baby weighing between 1,501 to 2,500 g, very low birth weight is a baby between 1,001 and 1,500 and babies with weight less than 1,000 g at birth are defined as extremely low birth weight.

BLOOD VOLUME AND HAEMOGLOBIN

Newborn blood volumes are affected by the timing of cord clamping, and a haematocrit above 50% indicates placental transfusion. Blood volume is 85–100 mL/kg in preterm neonates and remains at about 85 mL/kg for term neonates. The blood volume per kilogram becomes equal to that of an adult by 3 months, when it is, and remains at, 70 mL/kg.

Almost 80% of the circulating haemoglobin in the neonate is fetal haemoglobin, which has a lower oxygen-carrying capacity than adult haemoglobin. The p50 of adult haemoglobin (50% of the bound oxygen is released) is 27 mmHg, while that of fetal haemoglobin is 6–8 mmHg. This contributes to the efficiency of the placental circulation; however, as the erythropoiesis progresses beyond 3–4 months, the fetal haemoglobin is replaced by the adult type. Thus, in a neonate, a lower peripheral oxygen level is required before oxygen levels are released from the fetal haemoglobin.

THERMOREGULATION

Neonates have poor thermoregulation and extremes of temperature should be avoided. Newborns have a relatively large surface area along with a small mass. Heat loss can occur due to evaporation, conduction, convection and radiation. Critical temperature is defined as the temperature that necessitates a metabolic response to adapt. Infants rely on non-shivering thermogenesis and brown adipose tissue to maintain temperature homeostasis. The brown fat metabolism works in a manner whereby energy is released as heat; this in turn may be rendered inadequate by the vasopressors and anaesthetic agents used in anaesthesia and surgery and nutritional depletion.

Incubators are the best mechanism for managing surgical neonates. However, logistical concerns of drains and dressings may necessitate the use of open care radiant warmers, which may cause more insensible water loss.

PREOPERATIVE AND ANAESTHESIA CONCERNS

Preoperative planning and preparation for the paediatric patient is crucial because surgery can be an anxious and stressful time for children and their families. Surgery in the paediatric patient relies on the use of general anaesthesia for most cases. The preoperative management of anaesthesia in children differs from that in adults. These differences include:

- Cognitive and age-appropriate language
- Assessing a patient's developmental stage
- Addressing the patient and parents' anxiety
- Understanding the dynamics of the patient's family

Providing anaesthesia for children presents many challenges, but careful preoperative assessment and preparation can enable the experience to be positive for the child, parents and anaesthetist. The aims of the preoperative assessment are to gather information from the notes, child and family, plan an appropriate anaesthetic technique, allow an assessment of risk, deliver information to the child and family, and enable a degree of psychological preparation for the anaesthetic experience and adequate management of postoperative pain.

PRE-ANAESTHETIC ASSESSMENT

The necessary paediatric pre-anaesthetic assessments that occur include collecting information about any allergies, previous anaesthesia experiences, airway techniques that have worked or failed in the past and the location of a reliable intravenous (IV) access in patients.

Premature infants are at an increased risk of postoperative apnoea and bradycardia, extending up to 48–50 weeks post gestational age, and require close postoperative monitoring. Infants and children with congenital cardiac disease need thorough evaluation of their current anatomy and previous operations to evaluate their need for further cardiac management and endocarditis prophylaxis.

As a minimum, the evaluation for a murmur should include a thorough medical history and a physical evaluation, as well as an electrocardiogram. Intracardiac shunts (e.g. ventricular septal defect) need to be identified in the preoperative period, as anaesthetic agents can affect the functioning of these shunts.

The presence of recent or preoperative acute airway infections in any child is a frequent challenge for anaesthesiologists. Such infections are responsible for a significant increase in intraoperative and postoperative respiratory hypoxia and related complications.

With respiratory infections, endotracheal intubation increases the risk of respiratory complications 11-fold in children (especially in those younger than 5 years). Using a mask airway, if appropriate, instead of tracheal intubation may reduce the risk, including in emergency situations. Specifically, a history of malignant hyperthermia, pseudocholinesterase deficiency, postoperative nausea and vomiting, congenital myopathies and bleeding disorders should be explored.

No complex laboratory work is indicated for healthy children undergoing a procedure with minimal anticipated blood loss. A haematocrit test may be ordered if significant blood loss is expected and may be required for infants at some institutions. Bleeding time, prothrombin time, partial thromboplastin time and platelet count have not proven to be reliable predictors of bleeding risk; therefore, their measurement is not routinely recommended. Preoperative laboratory tests, if obtained, should be reviewed in a timely manner. The list of medications that the child is taking must be reviewed, and appropriate instructions must be given to stop or continue the medications as needed.

Age-specific considerations for paediatric patients must be explicitly addressed. These include (by age group):

- *0 to 6 months*: patients are completely unaware of their surroundings and it is a time of maximal parental anxiety.
- *6 months to 4 years*: patients experience maximum stranger and separation anxiety.
- *4 to 8 years*: patients begin to understand processes and explanations. However, their fear of separation remains and they are concerned about body integrity.
- *8 years to adolescence*: patients tolerate separation and understand processes and explanations. Adolescent patients are independent. They may have issues regarding self-esteem and body image.

FASTING GUIDELINES

Fasting guidelines are designed to minimise gastric volume and to reduce the risk of pulmonary aspiration. The generally agreed guidelines are that clear liquids can be given up to 1–2 hours before surgery and breast milk up to 4 hours before surgery, that formula/non-human milk and a light meal can be given up to 6 hours before surgery and that solids can be given up to 8 hours before surgery.[1] These guidelines allow for a smoother preoperative course and a more comfortable child. The preoperative *nil per os* (nothing by mouth) instructions should be explicitly explained to the parent because they are frequently misunderstood.

The care of children in the preoperative area should be centred on a compassionate and team-based approach. It begins with an empathic approach towards the family.

SURGICAL ANATOMY, INCISIONS AND SPECIAL CONSIDERATIONS

The principles of surgery in children in terms of incisions, space and healing are different. Infants and small children have a wide abdomen, broad costal margins and a wide pelvis. The ribs are flatter and wider, and the umbilicus is low lying. The paediatric abdomen is square-shaped, compared with the rectangle in adults. This has several implications for the incision and safety of the underlying organs. The liver and spleen are more prone to trauma, as they occupy a good part of the upper abdomen. The urinary bladder is also intra-abdominal rather than pelvic. Surgical incisions must be planned based on these differences in the anatomy of the child.

INCISIONS

The incision must be carefully sited after taking into consideration the underlying pathology to be addressed. Incisions can be upper transverse, subcostal, Pfannenstiel, Lanz and occasionally midline in the older child.

In children, the right upper transverse incision provides good exposure to almost all areas of the abdomen except the pelvis. This incision is also known to have a lower risk of wound dehiscence.[2] This incision can start 1–2 cm above the umbilicus, and progression should be in layers. Care must be taken to coagulate even the smaller vessels, as blood loss should be kept to the minimum. Once the falciform ligament is cut, the ligamentum teres should be ligated with absorbable sutures and divided.

Subcostal incisions may be used for liver, spleen and suprarenal lesions. This may be extended to a 'chevron' or to the 'Mercedes-Benz' incision, in case better exposure is required. The left Lanz is a muscle-cutting hockey stick incision that provides good exposure for the colon, especially as an an approach for sigmoid colostomy.

Siting a colostomy may be challenging in a smaller child, especially in a neonate due to the low-lying umbilicus. A distended abdomen due to the underlying bowel distension may make the process even more difficult. Care must be taken to allow enough space for application of a small colostomy bag, away from bony points and the incision.

LAPAROSCOPIC APPROACH

The paediatric abdominal wall is considerably lax and accommodating. This helps in the creation of a working pneumoperitoneum. The pressure of the pneumoperitoneum must be in compliance with the diaphragmatic splinting and the end tidal CO_2. Entry to the abdomen should be by the open technique, due to the smaller working space, to avoid any visceral injury. Once the camera port is in place, the other ports can be safely inserted under vision. Usually, 5 mm and 3 mm ports for cameras and instruments can be used safely. In older children, a 10 mm umbilical port may be more useful for better vision and easier removal of diseased organs.

SPECIFIC SURGICAL CONDITIONS

ACUTE SCROTAL CONDITIONS

Acute scrotal conditions are one of the most common paediatric genitourinary emergencies.[3] There are several scrotal conditions that can present acutely, including testicular torsion, torsion of the appendix of the testis, epididymo-orchitis and idiopathic scrotal oedema.[4,5]

An accurate history and clinical examination often result in a correct diagnosis, but clinical features can be misleading and may lead to a missed, or delayed, diagnosis of true testicular torsion, hence the need for a low threshold for scrotal exploration in all cases of an acute scrotum for definitive diagnosis, effective pain relief and testicular salvage.[4] The salvage rate has been estimated to be about 50% for all cases of testicular torsion and depends on three factors: prompt presentation, prompt diagnosis and immediate surgical exploration.[6]

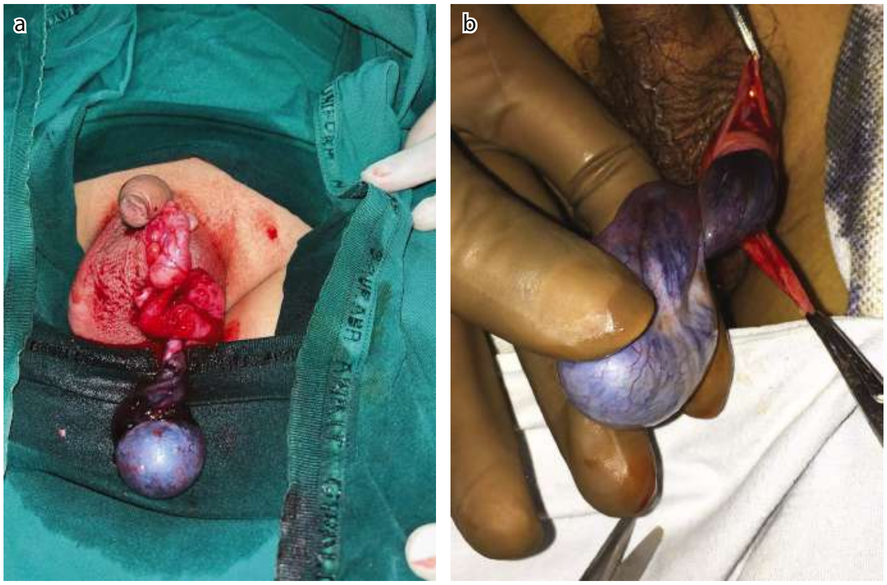
The child's age is the first clue to the cause of the acute scrotum because torsion of the appendix testis/epididymis is more common in prepubertal boys, whereas true testicular torsion is more commonly presents in adolescents and newborns.[7] However, this is not always evident in the paediatric population, especially when scrotal wall changes hinder evaluation of the testis.[8,9] Moreover, young children cannot give a precise history, and they localise pain poorly, such that abdominal pain may be the only presenting symptom.

In older children, the pain and embarrassment often prevent the clinician from localising the tenderness precisely between the upper and lower poles of the involved testicle, making it difficult to make a diagnosis of either torsion of the appendix of the testis or testicular torsion. While the clinical signs may not be absolute, a careful examination can allow the surgeon to reach a reasonable diagnosis.

Testicular torsion

The classic clinical features of testicular torsion are severe unilateral scrotal pain and tenderness, often associated with abdominal pain, nausea and vomiting. Swelling and erythema are common features with an acute scrotum, but more so in true testicular torsion. Pyuria and bacteriuria can be present in testicular torsion, but fever is uncommon. Fever, vomiting and pyuria can mislead inexperienced clinicians who might consider an infectious aetiology such as epididymo-orchitis, which is uncommon in prepubertal sexually inactive males. Important clinical signs are asymmetry, discrepancies in the size and position of the testes (which may be horizontal in testicular torsion), the degree of swelling and any changes to the overlying skin. The cremasteric reflex (elevation of the testicle due to contraction of the cremaster muscle on stroking the medial aspect of the thigh) is absent in torsion.

The diagnosis of an acute scrotum suspected to be testicular torsion is based on signs and symptoms, as well as a high clinical suspicion. We do not advocate any radiological examination if testicular torsion is suspected. Radiology may unnecessarily delay time to treatment. Colour Doppler and high-resolution ultrasonography are advocated by several authors for the diagnosis of an acute scrotum in children, as these methods have high sensitivity and specificity in experienced hands. However, organising radiological investigations, especially after-hours, is time consuming and operator dependent and puts an ischaemic testis at risk of irreversible damage. Finally, testicular perfusion can be maintained for a prolonged period in the presence of testicular torsion, possibly due to specific anatomical variables.[10] It should be emphasised that ultrasonography can help confirm a diagnosis other than testicular torsion but cannot be used to exclude torsion.[11]



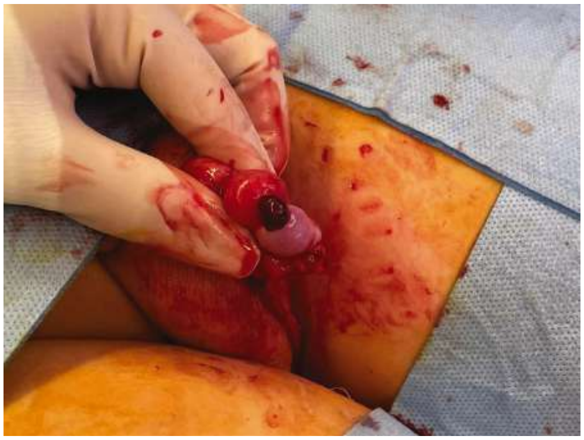
27.1 Testicular torsion. ⏎

Ischaemia can occur as soon as 4 hours after torsion and is almost certain after 24 hours.[11] Detorsion in less than 6 hours or after 24 hours leads to testicular salvage rates of 90% and less than 10%, respectively.[6] Urgent scrotal exploration should be performed in all suspected and doubtful cases (Figure 27.1). This can be done either through a midline incision allowing access to both testes or through two small transverse incisions in the rugae over each testis.

If torsion is found, the testis should be detorted and placed in warm saline-soaked swabs and observed for up to 10 minutes. If the testis is viable, a three-point or four-point fixation should be performed at the poles and the medial edge using a fine non-absorbable suture such as polypropylene. The contralateral testis must also be fixed, as there is up to a 40% risk of contralateral torsion.[12]

If the testis fails to reperfuse at exploration, the testis may or may not be removed at this time. If left *in situ*, the parents and patient need to be informed about the risk of atrophy or infection. If the testis is deemed non-viable and consent has been obtained, an orchiectomy is performed via the same incision. If the testis is normal and not torted, fixation is not recommended, as sutures could breach the testes–blood barrier and risk antisperm antibodies developing, which may affect fertility.

During the preoperative consent procedure, patients and their parents should be informed of several key problems related to the procedure. Fixation of both testes is often required. Patients should be warned that the sutures can sometimes be felt through the scrotal skin, causing pain or irritation. Although rare, despite detorsion and fixation, the testes can shrink and atrophy with no guarantee of future fertility.[13]



27.2 Torsion of the testicular appendage. ⏎

Torsion of testicular appendage

A diagnosis of torsion of the appendix of the testis (Figure 27.2) can be made reliably on clinical examination when the child feels point tenderness on the affected testis. This can be elicited on the child by a calm examination after giving adequate analgesia to the child. In fair-skinned children, the blue dot sign may be seen. The cremasteric reflex is usually present and the lie of the testis appears normal.

If the diagnosis of torsion of a testicular appendage is certain, it can be managed conservatively with adequate analgesia. If there is any doubt about the diagnosis, a surgical exploration must be performed.

If torsion of the testicular appendage is seen at the time of surgery, it can be ligated and excised. Removal of the opposite appendage is not indicated.[14]

Idiopathic acute scrotal oedema

Pathological signs seen in torsion are not usually present in idiopathic acute scrotal oedema, which is an important differential diagnosis, but often a diagnosis made by exclusion.[5] It affects boys more than adults, and 60–90% of cases are in children less than 10 years old.

The classical features are extensive erythema and oedema (which may progress to the groin, perineum and penile regions), which is seen as hypervascularity of the scrotal wall on colour/power Doppler and known as the 'fountain sign'.[6] It is important to distinguish this condition from other causes, as it is self-limiting and resolves within 3–5 days. Although multiple aetiologies have been suggested, a connection to prior intestinal worm infestation has been described.[7] The condition is managed conservatively and symptomatically. Antihistamines may be used.

Testicular trauma

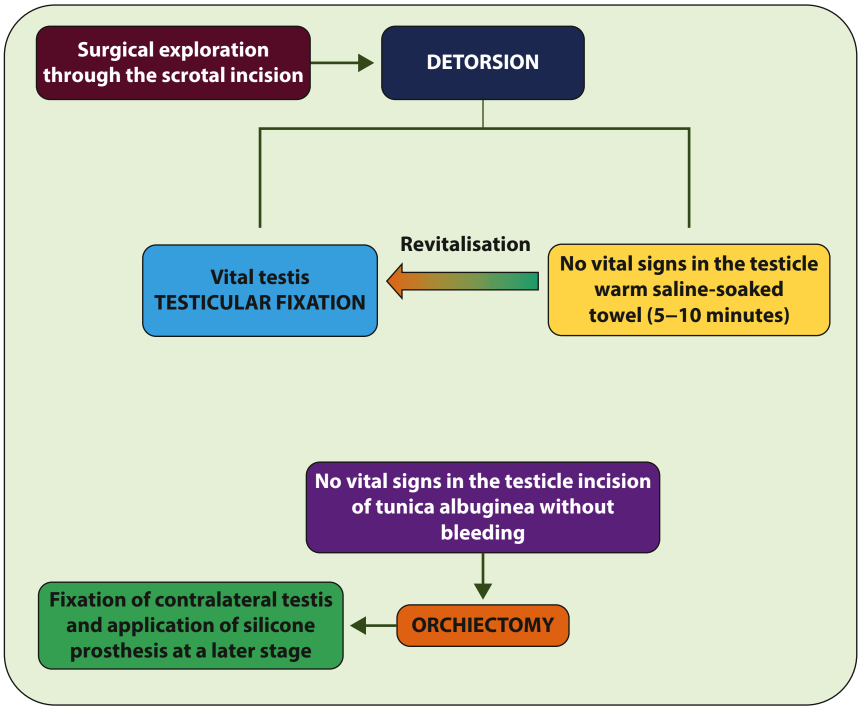
Blunt trauma, usually in contact sports, may cause testicular injury, but this is rare due to the scrotum position and mobility. Injury is more common on the right side because of the greater propensity for the testes to be trapped against the pubis or inner thigh.[15] Testicular rupture is a rip or tear in the tunica albuginea resulting in extrusion of the testicular contents. Prompt surgical intervention is crucial, as a ruptured testis can be salvaged, with a high success rate, if surgical repair is performed within 72 hours of testicular injury (Figure 27.3).[15]

ACUTE APPENDICITIS

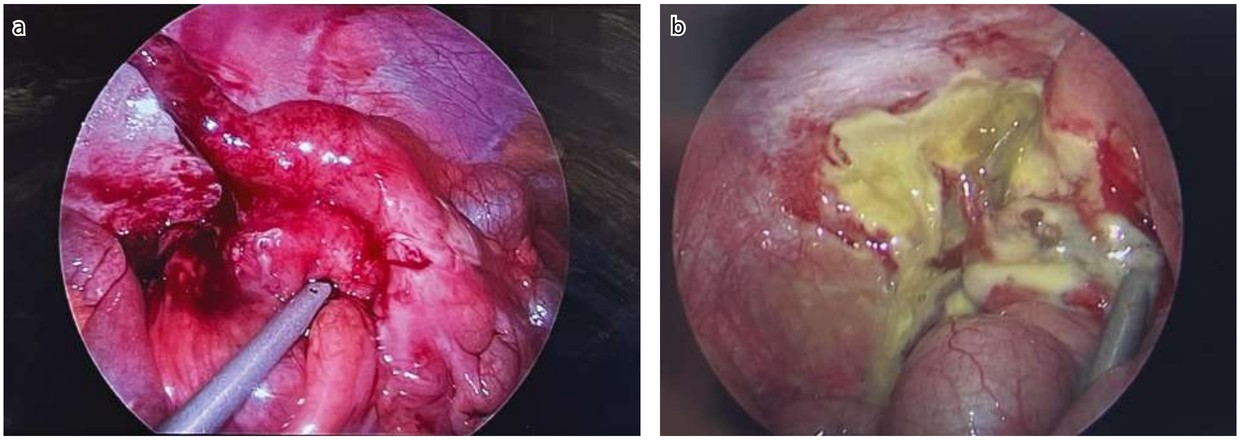
Acute appendicitis is the most common surgical emergency in the paediatric population and can present diagnostic challenges, due to atypical signs and symptoms compared with adults. The peak incidence of appendicitis is between 12 and 18 years. The diagnosis of acute appendicitis has historically been a clinical diagnosis, but various adjuncts have been used to aid the diagnosis, including serum inflammatory markers and radiological investigations.

The symptomatology of appendicitis in children can range from a vague periumbilical pain, diffuse abdominal pain or tenderness to localisation in the right lower quadrant. The classical triad of colicky central abdominal pain, nausea/vomiting and pain that moves to the right iliac fossa is uncommon. This pain may be accompanied by fever, dysuria and diarrhoea, depending on the position of the appendix, the severity of inflammation and perforation.

While a lot of named signs have been defined in the literature and in textbooks, the paediatric surgeon may find it challenging and the child may find it stressful for those signs to be elicited. The best method is to examine the abdomen after the child has been made


Surgical exploration through the scrotal incision
DETORSION
Revitalisation
Vital testis TESTICULAR FIXATION
No vital signs in the testicle warm saline-soaked towel (5–10 minutes)
No vital signs in the testicle incision of tunica albuginea without bleeding
ORCHIECTOMY
Fixation of contralateral testis and application of silicone prosthesis at a later stage

27.3 Management of testicular torsion. ⏎



27.4 Appendicitis. (a) Simple. (b) Complicated. ⏎

comfortable and has had analgesia. The surgeon may be able to better elicit signs without causing distress to the child and thus facilitate a successful clinical diagnosis. Tenderness in the right lower quadrant of the abdomen is the most useful detectable sign.

A diagnosis of appendicitis in children can be challenging, as they may have difficulty in describing the pain, especially in the younger age group. Additionally, a third of patients in the paediatric population have atypical presentations of acute appendicitis. Taking these and other factors into account, a 28–57% rate of misdiagnosis has been described.

Radiological investigations, such as abdominal ultrasound and computed tomography (CT), are very sensitive in the diagnosis of appendicitis. However, there are concerns about availability, radiation risk and experience in interpretation of imaging, leading to varying results reported from around the world and interoperator variability.

The hallmark features of appendicitis on ultrasound are a blind ending tubular structure with a diameter greater than 6 mm, along with associated signs of surrounding inflammation, which may include mesenteric fat stranding, fluid collection around the appendix and probe tenderness in the right lower quadrant. In cases where the ultrasonologist is not able to identify the appendix and clinical signs are not conclusive, a CT scan may be warranted, if available.

In male children, a clinical picture of acute appendicitis, together with raised levels of acute phase reactants, may be enough to make a diagnosis. In female children, an ultrasound may be needed to differentiate acute appendicitis from any adnexal pathology.

Laboratory investigations, using acute phase reactants, are regularly ordered in the emergency department. There are a variety of markers that have been described for appendicitis but the ones most used are total leucocyte counts, C-reactive protein and procalcitonin. There are conflicting reports regarding the usefulness of these investigations. Opinions range from these tests having no diagnostic value to being extremely sensitive in the diagnosis of appendicitis. Most paediatric centres do place importance on the levels of these acute phase reactants to help reach a diagnosis of acute appendicitis. Several studies have shown that a combination of inflammatory markers, total leucocyte count, neutrophils and C-reactive protein, measured together, increases the specificity and positive predictive value in diagnosing acute appendicitis. Although diagnostic scoring systems are employed in some centres for acute appendicitis, the World Society of Emergency Surgery Jerusalem guidelines[16] recognise their limitations.

Differentiating between uncomplicated appendicitis and complicated appendicitis (which can range from an inflamed but intact appendix to conditions such as perforation, peritonitis or a gangrenous appendix) is crucial for determining the appropriate management strategy. In Western countries, this differentiation has gained significance, as better diagnosis and medical treatment have led to proposals for routine non-operative management for children with uncomplicated appendicitis.[17] The options for simple appendicitis (Figure 27.4a), without an appendicolith, range from non-operative management using antibiotics to an emergency appendectomy. In a child with complicated appendicitis (Figure 27.4b), especially with a collection, surgeons might still opt for an appendectomy or for drainage of the collection, generally under radiological guidance with an interval appendectomy 6–12 weeks later.

The current standard of care for the operative management of acute appendicitis is laparoscopic appendectomy, which is safe when performed by an experienced surgeon, is usually technically easy and has a lower rate of surgical site infections than an open approach. Three 5 mm ports are usually used for an appendectomy. The umbilical port, inserted by an open cutdown technique, is used for visualisation, while the working ports may be placed in the left and right lower quadrants or the left lower quadrants, with a suprapubic port if necessary. It is always advisable to keep the urinary bladder empty, either by asking the child to pass urine before induction of anaesthesia or by inserting a urinary catheter after induction.

The appendicular artery in the mesoappendix is sealed with coagulating diathermy current or a clip. Usually, more advanced energy devices are not needed. The appendix may be ligated using premade commercially available extracorporeal loops or by an intracorporeal knotting technique using absorbable material. The appendix may be removed in an endobag or similar appliance.

While laparoscopic appendectomy is safe, complications can include injury to the adjacent bowel, injury to the urinary bladder and retention of an appendicolith in the abdominal cavity leading to abscess formation.

Open appendectomy may be needed when laparoscopic equipment or surgical expertise in laparoscopy is unavailable. Open appendectomy may be carried out via the usual incisions (Lanz, McBurney's, etc.) used in adult appendectomy. Drains are usually not advised following an appendectomy in the paediatric age group. Surgery for complicated appendicitis may lead to postoperative abscess formation, which is usually drained under radiological guidance. The use and duration of postoperative antibiotic therapy for appendicitis is controversial.[16]

Children with simple appendicitis should receive a single dose of broad-spectrum antibiotic. In complicated appendicitis, antibiotics effective against Gram-negative organisms and anaerobes may be needed. No postoperative antibiotic therapy is advocated in children with simple, uncomplicated appendicitis. In complicated appendicitis, the duration of antibiotics may be from 5 to 7 days. Oral antibiotics, where tolerated, have been found to be as efficacious as IV antibiotics.

Recent evidence suggests that most children with uncomplicated appendicitis, in the absence of an appendicolith, may be offered non-operative management. The decision for non-operative management has usually been with the benefit of imaging such as ultrasound or CT. Children are considered for either non-operative or operative management as per the assessment of the surgeon and preferences of the patient and parents.[18]

CIRCUMCISION

Circumcision is one of the most common operations performed in neonates, infants and children around the world. Circumcision in males consists of the removal of a substantial amount of the foreskin. Male circumcision has been shown to reduce the incidence of urinary tract infections, HIV transmission and other sexually transmitted infections, and penile cancer.[19,20]

Circumcision is usually performed in the newborn period or deferred to infancy due to low birth weight or prematurity. Circumcision in later childhood may be performed to reduce urinary tract infections, especially in children with renal tract anomalies, tight pathological phimosis or balanitis xerotica obliterans. Circumcision has been shown to decrease the pathogenic flora that may collect under the foreskin, leading to urinary tract infections or sexually transmitted diseases.

Prior to performing a circumcision, the penis should be examined carefully for anomalies, particularly the position of the meatus. If an anomaly is found, the circumcision should be deferred and the child referred to a specialist centre. Circumcision in children is usually performed under general anaesthesia. Postoperative pain may be managed using local penile blocks.

Surgical technique

There are many ways to circumcise. Traditional methods of circumcision involve a double-incision technique on the inner and outer side of the prepuce and then dividing the two layers. An alternative would be to perform a dorsal slit and then excise the prepuce at the level of the coronal sulcus. It is imperative to ensure good control of the frenulum and the vessels within it, as most operative and postoperative bleeding will occur from inadequately controlled frenular vessels. The incision is closed with 5/0 or 6/0 absorbable sutures. Particular attention should be paid to haemostasis prior to closure. Circumcision in newborns can be safely performed using devices such as Plastibell, a Mogen clamp or a Gomco clamp.[21]

Complications after circumcision are uncommon if a good technique is followed with careful haemostasis. However, complications occur in up to 3% of patients. Complications include:

- Bleeding
- Infection
- Lacerations
- Partial amputation of the glans
- Urethral or meatal injury
- Urinary retention

Non-acute complications may include too much, or too little, skin being trimmed, penile chordee and meatal stenosis.

PAEDIATRIC INGUINAL HERNIA

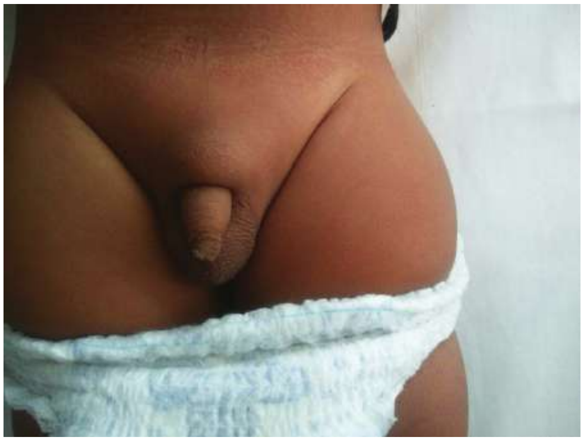
Inguinal herniotomy is one of the most common operations performed globally by paediatric surgeons. The incidence ranges between 0.8% and 5%. Most inguinal hernias manifest during the first year of life, with more than 80% occurring within the first few months after birth. There is a significantly higher incidence of inguinal hernias in preterm infants ranging between 16% and 25%.[22] Almost 60% of hernias are right sided and hernias are at least three times more common in boys.[23]

The processus vaginalis is an extension of the peritoneum through the internal ring, and a patent processus vaginalis is essentially the embryological basis of this common condition. The intra-abdominal testis passes through the inguinal canal during the third trimester, elongating the processus in this embryological event. The proximal processus obliterates and the distal portion remains as the tunica vaginalis over the testes. In the case of the non-obliteration of the processus vaginalis, an inguinal hernia is a consequence.

Clinical symptoms and examination

There may be a history of intermittent inguino-scrotal or inguino-labial bulge. In babies and small children, the swelling (Figure 27.5) may be noted by a parent or caregiver during a bath or a diaper change. Hernias are usually asymptomatic, and the parents must be counselled of the danger signs of incarceration or strangulation. Incarceration is caused by the entrapment of the bowel. This leads to pain, discomfort and irritability. If incarceration persists, it may lead to bowel strangulation and subsequent perforation.

In clinical examination, the child may be allowed to strain by crying, coughing or using a Valsalva manoeuvre while standing and a bulge may appear. If no mass is appreciated, then the spermatic cord may be palpated by a finger over the pubic tubercle. The thickened cord compared with the normal side is referred to as the ‘silk glove sign’ or sometimes the ‘plastic baggy sign’. Quite often, a digital photograph on the parent’s phone is acceptable as a diagnostic tool. Occasionally, a clear history by the parents, even in the absence of physical signs, may warrant an indication for an operation.



27.5 Male inguinal hernia. ⏎

Investigations

In some cases, an inguino-scrotal ultrasound, if available, may be helpful when there is doubt about the diagnosis. No radiological examination is generally necessary to diagnose an inguinal hernia.

Surgery

The surgery can be carried out in an ambulatory setting, that is, as a day case. In a patient with an incarcerated hernia that has been reduced, the recommendation is that surgery should be carried out after 24 hours allowing time for any oedema to reduce. In premature infants, the ideal time may be before discharge from the neonatal intensive care unit or, if the baby is well with no problems from the hernia, the surgery may be delayed until the postconceptional age of 60 weeks for improved tolerance to general anaesthesia. The fundamental principles of surgery for a paediatric hernia are a herniotomy and the high ligation of the peritoneal sac. The modified Ferguson approach is popular in the USA, and the Mitchell Banks technique is commonly used in Europe and the UK.

The patient is positioned supine on the operating table and the incision is made in the lower groin crease, just inferior and lateral to the pubic tubercle. The superficial ring lies inferior and lateral to the pubic tubercle. The skin and subcutaneous tissues are divided, and Camper’s fascia is spread with scissors to expose the glistening white Scarpa’s fascia. Scarpa’s fascia is held with forceps and divided by a sharp cut. The external oblique aponeurosis is identified and divided from the superficial to the deep ring. Once inside the inguinal canal, the inguinal ligament is the landmark for further dissection. Here, the ilioinguinal nerve and the iliohypogastric nerve are identified and swept away from the other contents of the inguinal canal.

The cremasteric fibres are spread antero-medially using a fine clamp and the silver glistening peritoneal ‘sac’ is identified and freed up. The cremasteric fascia is swept away, fibre by fibre, and the vas deferens and the spermatic vessels are also gently swept away. The vas is inherently close to the sac and must not be held by forceps and instead must be swept away with the cremasteric fibres closely associated. The sac is then held between clamps and divided. If a significant sac is present towards the testicular side, then the distal sac should be laid open. The proximal sac is dissected upwards to the deep ring until the 'yellow' preperitoneal fat is identified, indicating the deep ring. The sac is then twisted, taking care not to incorporate the vas or vessels, and ligated with an absorbable transfixation suture (usually 4/0 or 5/0). The testis is then pulled downwards in the scrotum and the external oblique aponeurosis is approximated. Scarpa's fascia is approximated, followed by subcutaneous tissue and skin.

In the Mitchell Banks technique, the external oblique is not divided and the sac is held through the superficial ring and divided. The basic anatomical principle is determined by the fact that the superficial and deep rings are almost superimposed in small children.

Female inguinal hernia

The ovary, the round ligament and often the Fallopian tube can be the contents of hernia in a girl. Rarely, in a phenotypic girl, the content within the sac may be testicular tissue, in cases of complete androgen insensitivity syndrome (CAIS).

The surgical repair in a girl is simpler, as the vas and vessels are not present. Care must be taken to check the contents for an ovary, round ligament or Fallopian tube. In up to 40% of girls, the sac may have a sliding component. If the sac is empty, the management is the same as in a male herniotomy. In the case of a sliding component, the sac and the round ligament may be attached to the conjoint tendon to provide support to the uterus. This is known as the Bastianelli manoeuvre. If the Fallopian tube is a sliding component of the sac, the Bevan procedure is performed, whereby the sac is divided and ligated above the tube and pushed back into the peritoneal cavity with a covering purse-string suture.

UNDESCENDED TESTIS

Undescended testis or cryptorchidism is a common anomaly, with the incidence being around 3–5%. The incidence is higher in preterm boys. In many infants, the testes descend by 12 weeks postnatally, such that the incidence is reduced to 2%.

Embryology of testicular descent

In the transabdominal phase, between 8 and 15 weeks, the testes are held by the cranial suspensory ligament near the abdominal inguinal wall by the growth of the gubernaculum. The cranial suspensory ligament regresses under the effect of testosterone and is controlled by the Müllerian-inhibiting substance (MIS). In the second phase, between the 28th and 35th weeks, the gubernacular growth is mediated by testosterone acting on the genitofemoral nerve and by the calcitonin gene-related peptide (CGRP). This further leads to scrotal migration of the testis.

Classification and types of undescended testis

Undescended testis may be defined as a testis that cannot be manipulated into the scrotum without traction on the spermatic cord. The positions of the testis can be described as per the normal tract of descent. The testis may be intra-abdominal, canalicular or in the superficial inguinal pouch, which is the space created by the tunica vaginalis in the groin. The superficial inguinal pouch is invested by Scarpa's fascia superficially and has a deep attachment to the fascia lata, caudal to the inguinal ligament.

In 80–90% of boys, the testes can be felt in the inguinal canal, best palpated by the flat of the hand in a relaxed child. If the testis is not palpable, it may be intra-abdominal (40–45%) or still be present in the canal (35–40%). The testis may also be absent in ~15% of patients due to testicular atrophy. The scrotum on the side of the cryptorchidism is hypoplastic.

Surgery

The three common reasons for orchidopexy are the risk of reduced fertility in an undescended testis, the risk of malignancy in adult life, and cosmetic and psychological reasons. Fertility is lower in men with a history of cryptorchidism. The risk of malignancy in adulthood is increased by 5- to 10-fold. The highest risk of malignancy is with an intra-abdominal testis, and the risks remain present even if the intra-abdominal testis has been brought into the scrotum.

Currently, the recommended age for orchidopexy is between 6 and 9 months of age, to prevent degeneration of germ cells and provide the testes with a cooler temperature in the scrotum. In centres with paediatric surgical expertise, an orchidopexy can be performed at 6 months, whereas, in low-volume centres, it may be prudent to wait until 12–18 months.

For an open orchidopexy, the initial steps are like those of an inguinal herniotomy. Once the inguinal canal is entered, the testes can be identified and then mobilised. The gubernacular attachment is identified by traction, which causes dimpling of the skin above, and lateral, to the neck of the scrotum. The gubernaculum is then divided and the patent processus vaginalis (or the peritoneal sac, which is invariably present) is teased off over the spermatic cord structures and ligated as in a herniotomy.

At the deep ring, the vessels are seen laterally and the vas deferens medially. If the spermatic cord is short, the fibres along the lateral edge can be carefully divided to gain some length. The method to ascertain descent into the scrotum is to see if the testes easily reach the opposite pubic tubercle without undue traction on the spermatic cord.

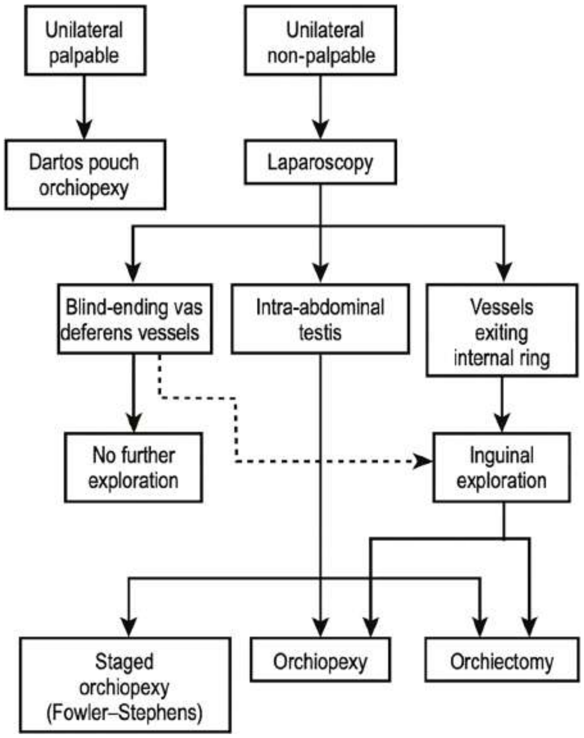
The Prentiss manoeuvre is when a testis is brought down medial to the inferior epigastric vessels. The little finger of the surgeon is pushed into the scrotum through the superficial ring and a skin incision is made over the bulge created by the finger. An adequate subcutaneous pouch (commonly known as the subdartos pouch) is made, and the glove of the finger is held by a Kelly clamp, after a small incision on the fascia. This clamp is then pulled into the inguinal canal and the testis is held, and gently pulled down, taking care not to twist the vas and vessels during descent. The buttonhole in the fascia is narrowed to keep the testes in the scrotum, within the dartos pouch. The inguinal and scrotal wounds can be closed with absorbable sutures.

Intra-abdominal and non-palpable testes

The gold standard in managing intra-abdominal testes is diagnostic laparoscopy (Figure 27.6), which should proceed once the testis has been located. It is prudent, especially in a chubby boy, to examine the inguinal canal under anaesthesia to detect a testis not felt previously at palpation in the awake patient.

A 5 mm, 30° telescope is introduced at the umbilicus, and two working 5 mm ports are used for mobilisation of the intra-abdominal testis. If the vas and vessels are blind ending, usually detected near the internal ring, then a 'vanishing' testis is diagnosed. The vas deferens may also be blind ending or may exit through the closed inguinal ring. Some surgeons may then open the scrotum to remove the atrophic testicular remnant (usually following perinatal torsion), but the need for this is debatable.

When an intra-abdominal testis is identified, the mobility can be assessed when it moves easily to the opposite internal ring. Once mobilised, the testis can be pulled down into the scrotum by a grasper and deposited in the subdartos pouch. In the case of a short spermatic cord, or vessels, a two-stage Fowler–Stephen's operation can be carried out, where the vessels are clipped far away from the testis. This promotes neovascularisation over the ensuing 6 months and, at a subsequent operation, the peritoneal folds, along with the testis, are mobilised and brought down comfortably.



27.6 Management of undescended testis. ⏎

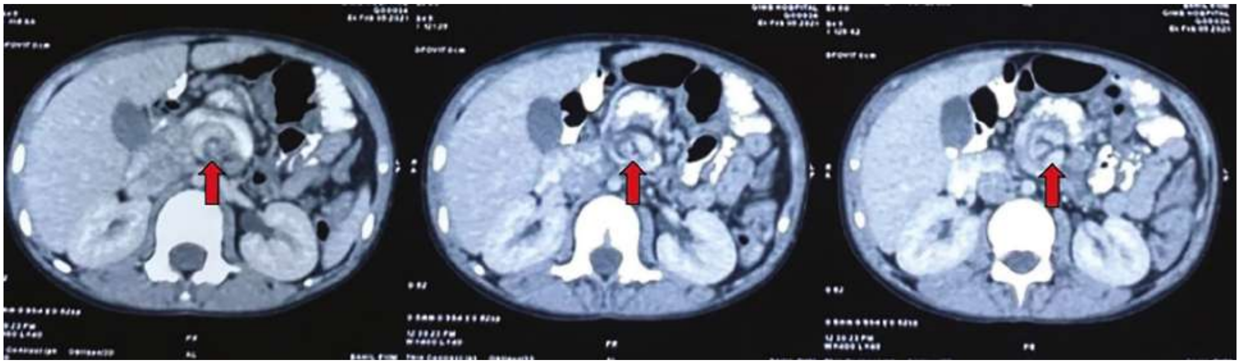
INTESTINAL MALROTATION

Bilious vomiting in children, especially in neonates, is a surgical emergency, and malrotation of the gut with, or without, volvulus must be ruled out without delay. Inadvertent delay may lead to complete loss of gut with devastating consequences for the child.

Malrotation results from interruption of typical intestinal rotation, and fixation, during fetal development. Malrotation can be acute or chronic with frequent delayed presentation. Acute malrotation is more common and is a dangerous condition presenting in the neonatal period and infancy.

Embryologically, rotation of duodenojejunal (DJ) and caeco-colic loops starts at the 5th week of intrauterine life with the superior mesenteric artery (SMA) as the axis. Initially, the jejunum, the rest of the small intestine, the caecum, the right colon and part of the transverse colon become extra-coelomic during the 5th to 8th week by undergoing 180° rotation and then, at the 8th to 10th week the bowel returns to the coelomic cavity. The small intestine is the first to return to the peritoneal cavity, which pushes the DJ to the left of the SMA and across the midline. The caecum and right colon undergo three 90° counterclockwise rotations by 12 weeks' gestation, and the caecum and right colon descend and come to lie in the right lower quadrant of the abdomen.

The classical picture of malrotation is that of the caecum lying to the left of the midline, the DJ flexure



27.7 Whirlpool sign on abdominal CT, with contrast, in malrotation (marked with red arrows). ⏎

lying to the right of the midline with a narrow bowel mesentery that lacks fixation, and peritoneal (Ladd's) bands passing from the caecum to the right side, across the duodenum. The primary concern is that midgut volvulus may occur following twisting of the narrow mesentery and thus threaten the venous outflow and, subsequently, the arterial inflow to the intestine. Children presenting with midgut volvulus are generally less than 1 month of age, have sudden onset bilious vomiting with a scaphoid abdomen and dehydration on examination. In late presentations, there may be features of abdominal wall erythema and shock.

Other rotational anomalies described are non-rotation, although incomplete rotation is the most common surgically treated form in which rotation is arrested at 180°. Reverse rotation is described, whereby the duodenum passes in front of the SMA, with the colon lying in front of the mesentery, posterior to the SMA. Internal small bowel hernias are also considered a subgroup of rotational anomalies.

There is a high rate of associated anomalies reported in infants with malrotation. Small bowel atresia may be a secondary outcome of antenatal volvulus. Other common associations include cardiac anomalies, anorectal malformation, duodenal web, trisomy 21 (Down syndrome) and congenital diaphragmatic hernia (most commonly on the right). Intestinal rotation anomalies are also seen in association with heterotaxy.

The most common clinical presentation of malrotation is with bilious vomiting during the first month of life (around 50% cases); this may be accompanied by abdominal distension or bleeding per rectum as a late sign. Presentation after the first month of life becomes more varied and may include episodic vomiting (often non-bilious), recurrent abdominal pain or simply failure to thrive, all of which may have been attributed to gastro-oesophageal reflux.

The diagnosis of malrotation is usually made by means of an upper gastrointestinal tract contrast examination. Plain radiographs in cases of established volvulus typically show air in the stomach and the proximal duodenum and a gasless appearance beyond. If the presentation is of an infant with peritonitis, then immediate laparotomy is mandated without wasting time on investigations such as a contrast study. Plain X-rays can be normal and do not exclude malrotation.

The diagnostic feature on upper gastrointestinal tract contrast examination is the C loop of the duodenum with a DJ flexure that does not pass to the left of the spinous process of the second lumbar vertebra, together with a low-lying pylorus. If volvulus is present, this may show as complete obstruction ('bird-beak') at the level of the proximal to mid-duodenum or as a 'corkscrew'-type appearance as the small bowel passes from posterior to anterior.

Ultrasonographic features have been described, namely reversal of the position of the SMA and superior mesenteric vein. Ultrasound is still not considered reliable enough to exclude malrotation, when clinically suspected, and depends on the expertise of the operator. However, in the future, by combining inversion of the SMA and superior mesenteric vein, the whirlpool sign (Figure 27.7) and an intraperitoneal transverse duodenum, sonography might be more valuable for accurately working up, or ruling out, suspected malrotation than an upper gastrointestinal tract contrast study, while avoiding radiation.

Preoperatively, the child is resuscitated with IV fluids and a nasogastric tube is inserted, especially in children who are actively vomiting. The surgical procedure to correct malrotation was described by William Ladd in 1936 and remains in widespread use. The objective is to derotate the midgut, straighten the duodenum, place the DJ junction in the right lower quadrant, widen the mesenteric root and place the ileocaecal junction in the left upper quadrant with or without an appendectomy, thus placing the intestine in a stable position. The basic steps include entry into the abdomen via a right supraumbilical transverse incision or a midline incision in older children, delivering the bowel out of the wound then counterclockwise derotation of the bowel (in cases with volvulus), division of Ladd's bands, broadening of the small bowel mesentery root and bowel placement as suggested above. Ladd's bands usually attach the duodenum to the caecum or the right colon, while some bands may extend to the gallbladder and liver. Dissection is performed close to the duodenum and hepatoduodenal ligament, and the end point is reached when the duodenum becomes straight.

The operating surgeon may be faced with the situation of volvulus and total midgut infarction at initial laparotomy. If midgut resection is undertaken at this stage, the infant is committed to short-gut syndrome, lifelong parenteral nutritional support and the possibility of intestinal transplantation in the future. A difficult ethical consideration arises, which should be managed with full discussion with the family to allow informed choice. If there is any question regarding viability, the bowel is returned to the abdominal cavity and a second-look laparotomy can be performed at 24–48 hours.

The laparoscopic Ladd's procedure is now well established, but it may not be appropriate in the emergency setting. The laparoscopic 'steering wheel' derotation technique is easy and provides a stepwise description of the laparoscopic derotation of volvulus associated with malrotation in children. In this, three ports are placed (one 5 mm umbilical and two paraumbilical 3 mm ports) and the bowel is inspected. In patients with volvulus, Ladd's bands are released first and then the caecum is rotated to the right hypochondrium and the ileum to the left hypochondrium. This is followed by again rotating the caecum to the left hypochondrium and ileum to the right; the manoeuvre is in the form of a steering wheel negotiating a sharp turn. Limitations in laparoscopy include difficulty in volvulus detorsion and possible injury by instruments required to derotate the bowel, limited working space and the potentially increased risk of future volvulus after a laparoscopic procedure due to fewer adhesions. The advantages of a laparoscopic procedure include a shorter hospital stay and earlier establishment of enteral nutrition.

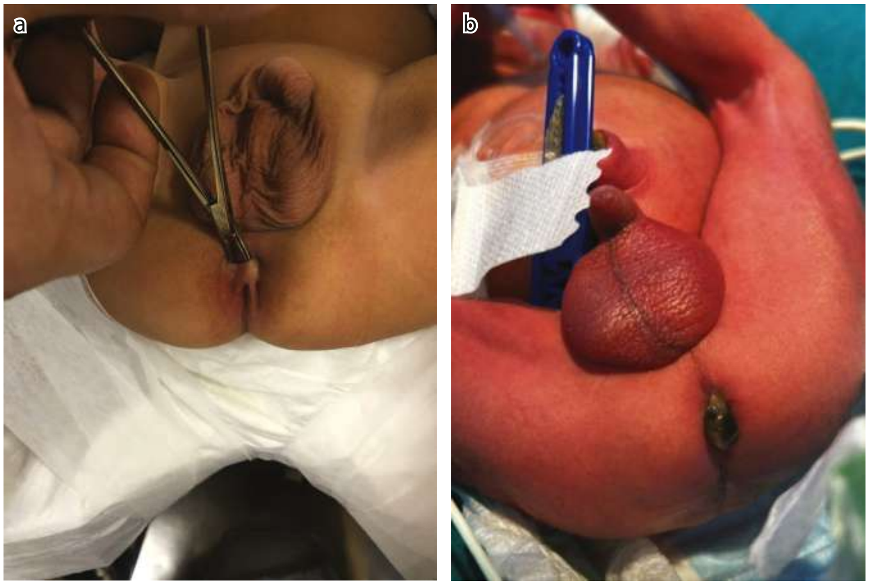
Resolution of symptoms occurs in the majority (around 90%) of patients who undergo Ladd's procedure. Complications of this procedure include adhesive small bowel obstruction (4–10%), intussusception (3%) and incisional hernia, intestinal dysmotility, perforated viscus and recurrent volvulus (around 1% each). Malrotation complications account for a significant proportion of children with short-gut syndrome. Mortality depends on whether bowel ischaemia is present, younger age and other clinical abnormalities and is approximately 3%.

ANORECTAL MALFORMATIONS AND NEONATAL COLOSTOMIES

Inguinal colostomies have been reported since the sixteenth century, and the first anoplasty is attributed to Amussat in 1853, when he mobilised the bowel and sutured it in the perineum. General surgeons may be asked to perform a colostomy in the neonatal period, most commonly for anorectal malformations.

Anorectal malformations

Anorectal malformations (Figure 27.8) have been reported since time immemorial. The initial proposed interventions involved cutting a hole in the perineum, with poor results and high mortality. The definitive



27.8 Anorectal malformations. (a) Bucket handle deformity. (b) Meconium pearl. ⏎

Table 27.4 Krickenbeck classification for anorectal malformation[24] ⏎

Major clinical groups	Rare/Regional variants
Perineal (cutaneous) fistula	Pouch colon
Rectourethral fistula • Bulbar • Prostatic	Rectal atresia/stenosis
Rectovesical fistula	Rectovaginal fistula
Vestibular fistula	H fistula
Cloaca	Others
No fistula	
Anal stenosis	

pull-through operations started in the mid-1900s. In the 1980s, a posterior sagittal approach was popularised by Pena and coworkers.

Anorectal malformations occur in 1 in 4,000–5,000 neonates and are slightly more common in boys. The most common connection between the rectum and the urogenital canal in boys is the rectourethral fistula (50%), followed by the rectoperineal fistula and the rectovesicular fistula (in approximately 10%). Imperforate anus without a fistula is seen in 10–12% and more than 50% of these children have associated trisomy 21 (Down syndrome).

In girls, the most common anomaly is the rectovestibular fistula, followed by the rectoperineal fistula. Cloacal anomalies are the third most common anomalies, in which the bladder, vagina and rectum open into a common channel.

Classifications Several classifications are available, but those with therapeutic implications are important for clinical care in the neonatal settings (Table 27.4).

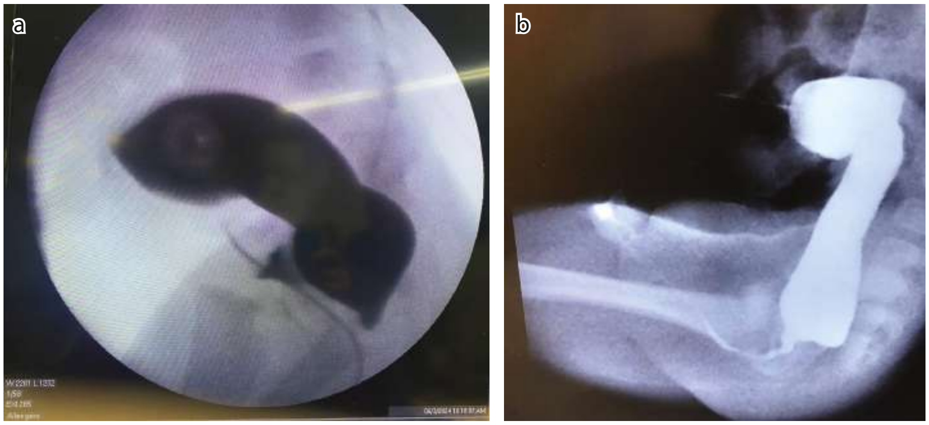
Most rectourethral fistulas in boys, and cloacas in girls, would warrant an urgent neonatal colostomy. Perineal fistula and vestibular fistulas may be amenable to local perineal procedures, with or without a colostomy.

Associated anomalies and initial management Associated anomalies are common in children with anorectal malformations, the most common being spinal and vertebral anomalies. This subset has worse bowel function. Cardiovascular anomalies are seen in around 35–40% of these patients; however, only 10–12% would require cardiovascular intervention. Genitourinary anomalies are quite common and include vesicoureteral reflux and renal agenesis. Males commonly have associated hypospadias and undescended testis. Gynaecological anomalies are seen in almost 40% of the girls with anorectal malformations. These commonly include hydrometrocolpos, vaginal atresias or vaginal agenesis. Uterine anomalies such as bicornuate uterus and uterus didelphys are also encountered.

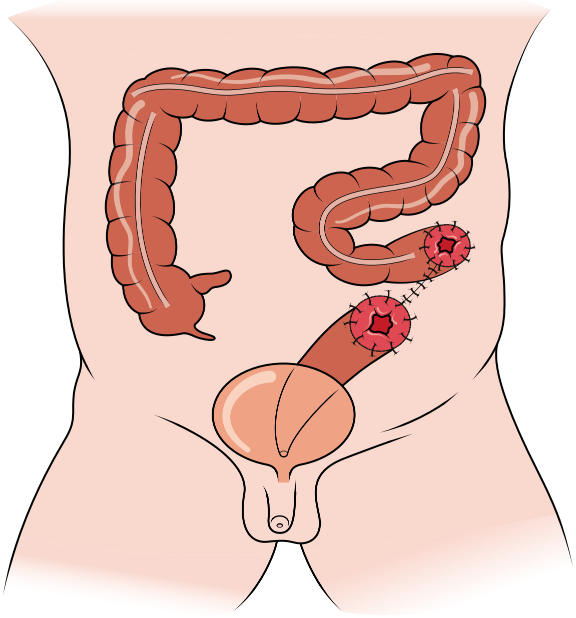
Neonatal colostomy

A high-divided sigmoid colostomy is preferable for the neonatal management of anorectal malformations with fistula in males and cloacal anomalies in female children. The transverse colostomy, even though technically easier, has several disadvantages in neonates. The large rectourethral fistulas commonly cause passage of urine into the bowel, which in turn would lead to metabolic acidosis. Transverse colostomies are more prone to prolapse and have an increased risk of colostomy diarrhoea causing weight loss and failure to thrive, especially in neonates. The mechanical bowel preparation and the distal colostogram (contrast study; Figure 27.9) to study the distal anatomy also becomes challenging with a transverse colostomy.

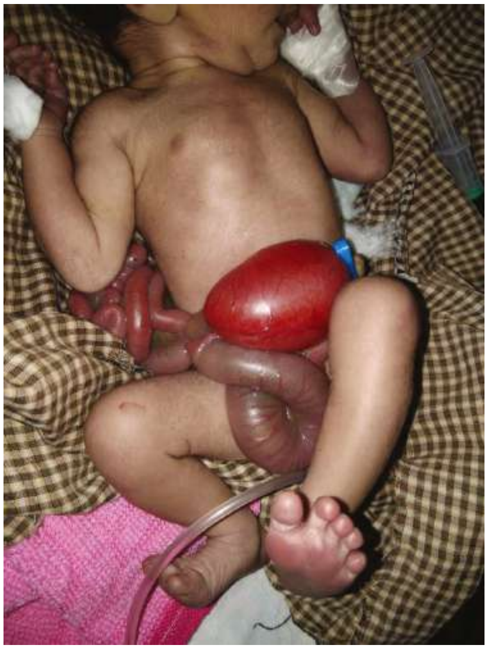
Sigmoid loop colostomies also have a higher chance of prolapse and may be commonly associated with incomplete diversion of the faecal stream. A very low colostomy may hamper the mobilisation of the distal pouch during subsequent definitive surgery.



27.9 Distal colostogram lateral views. ⏎



27.10 Neonatal colostomy. ⏎



27.11 Gastroschisis. ⏎

The divided sigmoid colostomy should be made through a left Lanz incision. The proximal sigmoid should be mobilised and matured in the upper end of the incision and the distal mucous fistula should be sited at the lower end of the incision. The distal mucous fistula should be small to reduce prolapse. The distance between both stomas should be sufficient to accommodate a neonatal colostomy bag (Figure 27.10). After the fascial closure, the distal loop should be given a thorough wash through, and all meconium should be aspirated to avoid a mega pouch and allow ease of a pull through.

A pressure-augmented contrast study is warranted before the definitive procedure. This entails the insertion of a Foley urinary catheter in the distal loop with inflation of the bulb. Care should be taken to not over-inflate and cause injury to the bowel. A water-soluble contrast medium is instilled under pressure to delineate the anatomy of the distal pouch and any fistula. This anatomical mapping would decide the approach to a definitive procedure (abdominal or posterior sagittal).

ABDOMINAL WALL DEFECTS

Gastroschisis and omphalocele reflect the two most common upper abdominal wall defects in newborns. Postnatal care consists of defect coverage, avoidance of fluid and heat loss, fluid administration and gastric decompression. Definitive treatment is achieved by defect reduction and abdominal wall closure. Different techniques, and timings, are used depending on the type and size of the defect, the abdominal domain and comorbidities of the child.

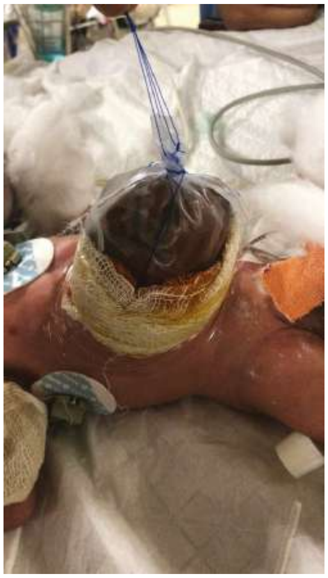
Gastroschisis

Gastroschisis (Figure 27.11) is one of the most common congenital abdominal wall defects in children. Children born with gastroschisis have a full-thickness paraumbilical abdominal wall defect, which is associated with evisceration of bowel and sometimes other organs. The defect typically measures 2–3 cm and is thought to result from involution of the right umbilical vein. Hence, the defect is mostly located to the right of the umbilical cord. Several mechanisms have been proposed for the pathogenesis of gastroschisis. Gastroschisis is typically accompanied by intestinal anomalies such as non-rotation, atresia and/or perforations but is rarely associated with other congenital or chromosomal anomalies, in contrast with omphalocele (Table 27.5). As the midgut is freely floating in the amniotic fluid, and not covered by a sac like in omphalocele, the intestine is typically thickened, oedematous and foreshortened/matted, and more so in late presentations. Complex gastroschisis occurs in about 11–28% of cases and is defined by the presence of intestinal complications including atresia (in 10–15%), perforation or necrosis. It is associated with increased morbidity and mortality and reduced survival rate.

Obstetricians mull over the conundrum of delivery in antenatally diagnosed cases. There has to be a balance between the exposure of intestines to amniotic fluid/other complications and the risks and

Table 27.5 Differences between gastroschisis and omphalocele

Gastroschisis	Omphalocele
Maternal serum alpha-fetoprotein highly elevated; younger maternal age	Maternal serum alpha-fetoprotein less elevated; average maternal age
Vaginal late preterm delivery preferred	Caesarean term delivery preferred
Defect right of umbilical cord	Umbilical/central defect
Contents open to amniotic fluid/air	Contents covered by sac
Associated intestinal anomalies	Associated chromosomal/cardiac anomalies (>50%)
Liver herniation rare	Liver herniation typical
Prognostic factor: condition of bowel	Prognostic factor: associated anomalies



27.12 Silo for gastroschisis.

complications of preterm delivery. Currently, limited evidence shows that elective late preterm delivery (i.e. planned delivery at 35–37 weeks' gestational age) is associated with less infectious complications and faster toleration of enteral nutrition. The optimal mode of delivery for children with gastroschisis has been much debated, but evidence is not sufficient to advocate the use of caesarean section, over vaginal delivery, for babies with gastroschisis. Ideally, it is important to notify a paediatric surgical centre with specific expertise in managing these cases as soon as possible, ideally before the delivery and with delivery taking place at the centre.

Immediate postnatal care is targeted to reduce fluid loss (by evaporation) and hypothermia, as well as to prevent infection. An oro-gastric/nasogastric tube should be inserted to decompress the stomach. IV access is needed for IV fluid resuscitation, sedation and antibiotic administration. The herniated viscera are covered with warm saline-soaked gauzes and the lower half of the newborn is placed in a plastic silo bag (Figure 27.12) with, or without, a spring. Alternatives to a silo bag include blood bags, which may need to be sutured in place. Kinking, especially of the mesenteric vessels, must be avoided; the optimal position is on the side in a lateral decubitus position.[25] This is especially important if the patient needs to be transported to another facility. If respiratory support is needed, nasal continuous positive airway pressure or high-flow O_2 should be avoided (to prevent filling the intestine with air). It is better to intubate with an endotracheal tube than to use non-invasive ventilation for this reason.

The primary goal in treatment of gastroschisis is to achieve a timely reduction of the herniated viscera, thereby avoiding harm to the viscera, while avoiding abdominal compartment syndrome. To minimise fluid loss and further intestinal impairment, reduction of the herniated viscera should be performed as soon as possible.[25] Primary reduction may lead to higher intra-abdominal pressure than staged reduction. A staged reduction reduces the duration of mechanical ventilation, the risk of infection and the time to enteral nutrition.

In the past, a silo was created using sterile plastic bags and typically sutured to the abdominal wall. Nowadays, a spring-loaded silo is commercially available. The intestine is placed inside the silo bag and the ring is placed under the fascia. The closed end of the silo bag can be suspended above the patient. Eviscerated organs are reduced by gravity and with additional manual pressure, and the silo volume is gradually reduced over a period of typically 5–7 days. The transparent silo allows herniated viscera to be inspected (for blood supply, perforation, etc.). Primary reduction with subsequent sutureless closure can be performed at the bedside (like in the staged reduction), often using a silo bag with warm saline, whereas primary reduction and sutured closure is typically undertaken in the operating theatre.

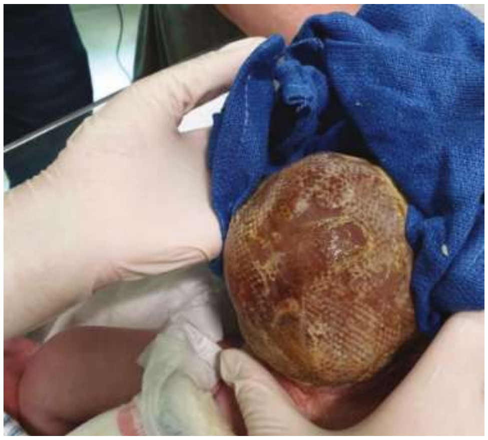
Ileus is very common after reduction, and a delayed return to oral/enteral nutrition of up to 4 weeks is expected and should not lead to unnecessary contrast studies or other procedures or therapies. In simple gastroschisis, the median time to tolerance of enteral feedings is about 3 weeks. If full enteral feeding is not achieved after 4–6 weeks due to persistent vomiting, a contrast study should be performed and, if there is any evidence of an obstruction (e.g. a missed atresia), a surgical exploration is warranted.

Omphalocele

The prevalence of omphalocele is between 1 in 4,000 and 1 in 10,000 live births. In omphaloceles (Figure 27.13), the abdominal defect is covered by a membranous sac, consisting of three layers comprising peritoneum, Wharton's jelly and amnion as the outermost layer. The umbilical cord vessels insert at the apex of the sac, which typically contains herniated abdominal contents. The contents can vary depending on the size of the abdominal wall defect and include intestine, liver, spleen, bladder and/or gonads. The sac covers, and protects, the herniated organs against harmful external influences. Most omphaloceles are in the midline of the abdomen where the umbilicus is located and can include a combination of small intestines, liver and/or stomach. Less commonly, omphaloceles can occur from more cranial defect folds (ectopia cordis, pentalogy of Cantrell) and caudal defect folds (cloacal exstrophy) in which the location will be epigastric or hypogastric. An omphalocele must be differentiated from gastroschisis, as there are several clinical differences between the two entities (see Table 27.5). Possible maternal risk factors associated with the development of omphalocele consist of maternal age <20 or >35 years, Afro-American ethnicity, maternal obesity (body mass index >30 kg/m^2), maternal disorders of glycaemic control and consequential fetal macrosomia (>4,000 g birth weight), and multiple births. Patient risk factors associated with omphalocele are primarily chromosomal anomalies. Omphalocele is especially common in patients with trisomy 18 (80–90% of cases) and Beckwith–Wiedemann syndrome (10–66% of cases). An accepted definition of a giant omphalocele is a defect diameter of ≥5 cm and/or herniated liver of >50–75%. Giant omphaloceles are associated with a risk of pulmonary hypoplasia.

Omphalocele management Once the decision has been made by the family to continue the pregnancy, if an omphalocele has been detected in a pregnant woman, ideally a multidisciplinary team involving obstetrics, paediatric surgeons and neonatologists should determine the best timing and route of delivery in consultation with the parents. The optimal route of delivery is still debated and deciding factors are the defect size, the organs exteriorised in the sac, the integrity of the sac and any other associated abnormalities. In cases of a minor omphalocele, vaginal delivery can be safe but, in larger defects or in cases where large parts of the liver are herniated, caesarean section is generally the preferred route of delivery to minimise the risk of significant bleeding, dystocia or sac disruption.

After delivery, initial resuscitation is the same as in children with gastroschisis and incudes frequent rectal decompression and prevention of bleeding from the liver. The choice and timing of treatment is dependent on the cardiopulmonary state of the infant, associated anomalies, the defect size and the severity of viscero-abdominal disproportion. The goal of any surgical treatment is to cover the fascial and skin defect and avoid an intolerable increase of intra-abdominal pressure. In general, treatment strategies can be classified in the following manner: immediate (primary) repair, staged repair with delayed primary closure, and delayed repair (paint and wait) with secondary closure of abdominal wall hernia (Table 27.6).



27.13 Omphalocele. ⏎

Primary repair Primary repair is best carried out in the operating room under general anaesthesia. The determination of blood group and a single dose of antibiotic prophylaxis are routinely performed preoperatively. The hernia sac is typically resected and the viscera reduced. Of note is that, upon resection of the hernia sac, a conversion into a paint and wait procedure or non-operative management will no longer be possible. The utmost care must be taken not to cause injury to the solid viscera, as this may lead to significant bleeding. If the sac is adherent to the liver surface, the peritoneal layer of the sac may be left in place to reduce the risk of liver injury. The umbilical vessels are ligated and the fascial defect is closed (vertically, transversely or via a purse-string suture).

Table 27.6 Omphalocele treatment ⏎

Treatment strategy	Management
Repair of hernias into the umbilical cord/small omphaloceles	Primary repair
Repair of larger (giant) omphaloceles without abdomino-visceral disproportion/pulmonary hypertension	Staged repair
Repair of giant omphaloceles with abdomino-visceral disproportion/pulmonary hypertension	Paint and wait

Staged repair Treatment options in cases of larger omphalocele with herniation of the liver, or a defect measuring ≥5 cm, consist of staged or delayed repair (paint and wait). The factors influencing decision-making include the degree of abdomino-visceral disproportion and pulmonary hypoplasia.

Several techniques have been described, with the goal to achieve a gradual visceral reduction over the course of 5–10 days, after which the abdominal wall can be closed. If preserved, the amniotic membrane may serve as an antiseptic barrier and silo. Infants undergoing staged repair will often need mechanical ventilatory support, adequate sedation with or without neuromuscular paralysis, and parenteral nutrition until repair of the abdominal wall has been performed. These procedures are best performed in a centre with paediatric surgical and intensive care facilities.

Schwartz et al.[26] described the use of a Silastic silo to allow for staged reduction. In this technique, the omphalocele sac is excised and the silastic sheeting is sewn to the rectus fascia or to the full-thickness abdominal wall. Serial reduction is performed by clamping and suturing or application of a linear stapler at the silo apex until a delayed closure is achieved. Visceral reduction can also be achieved by serial wrapping and compression with lipid gauzes and elastic bandages.

Various materials have been used for fascial closure in cases of large abdominal defects, including biological and synthetic meshes. Absorbable and biological mesh materials, mostly derived from human or porcine acellular dermis with scaffolds of collagen or elastin, are currently used. These materials have the advantage that growth factors facilitate ingrowth of tissue and vessels into the biological mesh. Non-absorbable synthetic meshes are no longer used.

The use of mesh for serial reduction of the abdominal wall defect may be a good alternative to the silo technique, especially in large defects (where a spring-loaded silo is easily displaced). In some cases, only skin flap closure over the abdominal defect may be warranted. Tissue expanders can be placed lateral to the defect in a subcutaneous pocket, to create skin flaps, and vacuum-assisted closure-type dressings and antibiotic ointments over biological meshes have also been reported as successful techniques facilitating incorporation and skin growth.

Delayed repair The strategy of delayed repair is often chosen for infants with giant omphalocele and/or a high degree of abdomino-visceral disproportion or children with low, or very low, birth weight, with marked pulmonary hypoplasia and/or other comorbidities. The goal of the paint and wait technique is to achieve an escharisation and eventual skin coverage of the viscera. In contrast with primary and staged repair, delayed repair always results in an abdominal hernia, which is closed in a second step once the child has grown (from 6 months to 3 years of age). To prevent infectious complications and to promote escharisation, topical combined escharotic/anti-infective agents can be applied. Silver sulfadiazine preparations and povidone iodine solutions are the most used agents. Sterile honey paint has also been used.[27] The hernia sac is painted daily with the escharotic agent and covered with dressings to protect the membrane and to avoid rupture. Thus, these patients have a shorter time to full enteral feeds and there is often no need for mechanical ventilatory support or neuromuscular paralysis.

Long-term complications and outcome

Complications can include the following:

- Gastro-oesophageal reflux
- Feeding difficulties
- Failure to thrive
- Chronic lung disease
- Inguinal hernias
- Abdominal compartment syndrome
- Midgut volvulus (seldom)
- Adhesive small bowel obstruction
- Neurodevelopmental and motor delays

In both types of abdominal wall defects (gastroschisis and omphalocele), tight closure of the defect may lead to abdominal compartment syndrome, which is defined by persistent intra-abdominal pressure above 20 mmHg (indirectly measured by bladder pressure) together with loss of function of one or more organs (e.g. anuria). The incidence of necrotising enterocolitis following gastroschisis has decreased from 15% historically to currently about 5%. Patients with gastroschisis may present with bowel obstruction due to adhesions (20–25%), typically in the first year of life, but obstruction may also occur later in life. Long-term outcomes of gastroschisis are generally excellent.

The complications often observed in children after the repair of omphalocele are gastro-oesophageal reflux disease, feeding difficulties, failure to thrive and chronic lung disease. Furthermore, in children with giant omphalocele, neurodevelopmental and motor delays occur more often.[28] Apart from abdominal hernias, as a result of increased intra-abdominal pressure, children after omphalocele repair also have a higher incidence of inguinal hernias.[29] More commonly (13–15%), patients present with adhesive small bowel obstructions.[30,31] Outcome and survival have improved dramatically over the last decades in children born with omphalocele.

HYPERTROPHIC PYLORIC STENOSIS

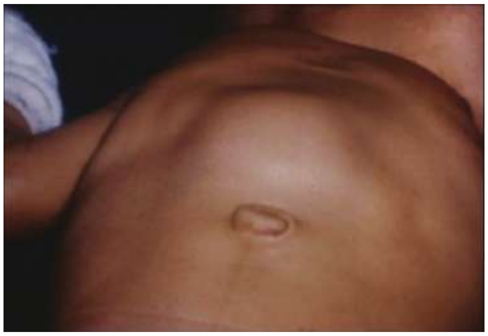
Noted as the most common cause of gastric outlet obstruction in infants, infantile hypertrophic pyloric stenosis (IHPS) has an incidence of 1.5–4 per 1,000 live births. There is a variability among races, a male preponderance and an increased risk among first-born infants with a positive family history of HPS. Other risk factors include certain ABO blood types, a higher risk in offspring of mothers who had pyloric stenosis as infants and environmental factors including erythromycin or azithromycin exposure and transpyloric feeding of premature babies.

In IHPS, the pylorus becomes enlarged and thickened, with gradually increasing obstruction. The most common clinical presentation is an infant with an onset of non-bilious vomiting at 2–8 weeks of age with a peak occurrence at 3–5 weeks. The vomiting becomes forceful over a period of some days. Gastritis or oesophagitis may sometimes occur giving rise to haematemesis. Infants with IHPS remain hungry after vomiting.

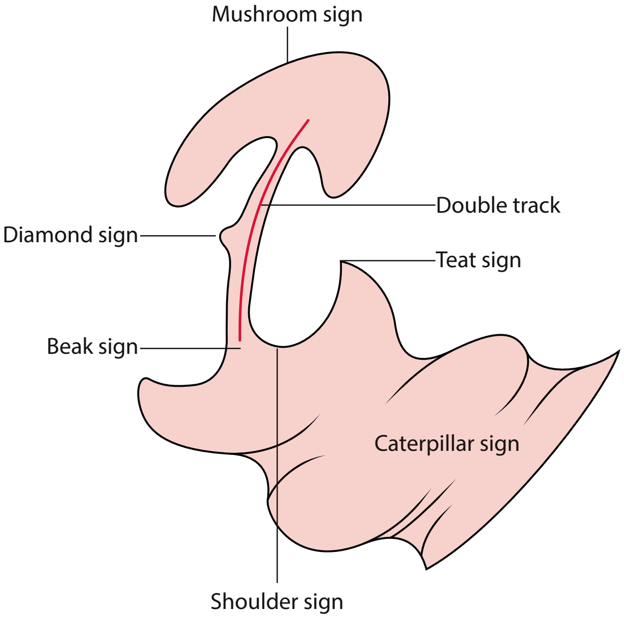
Late-presenting cases may be lethargic due to severe dehydration and metabolic disturbances. On examination, dehydration assessment and respiratory status are key to the initiation of effective management. Visible peristaltic waves and a visible/palpable pylorus may be present in the left upper part of the abdomen (Figure 27.14). In a calm and cooperative infant, a mass or olive-shaped lump may be felt in the right upper quadrant. However, this may not be easy to palpate due to a large overhanging lobe of an infantile liver.

Differentials of IHPS include pylorospasm and non-bilious vomiting due to medical causes, especially gastro-oesophageal reflux. The diagnosis in all cases is confirmed and established by ultrasonography. On an upper gastrointestinal tract contrast study, peristaltic waves of the distal stomach (caterpillar sign), a longer than usual pyloric canal, a thickened pylorus jutting into the antrum (beak sign), shouldering of the pyloric canal and temporary trapping of the contrast near the proximal pylorus (teat sign) may indicate pyloric stenosis (Figure 27.15). The ultrasonography findings that are highly suspicious of HPS include a pyloric muscle thickness wider than 4 mm, a pyloric canal length longer than 16 mm and a circular muscle diameter greater than 14 mm. These definition parameters must be relaxed in preterm infants.

Metabolically, in IHPS, there is hypochloraemic and hypokalaemic metabolic alkalosis, with paradoxical aciduria. Hyperbilirubinaemia may be seen in 2–5% cases. On blood gas analysis (preferably capillary blood gas), there are low serum levels of potassium and chloride and increased blood pH with a high blood bicarbonate level. These changes are explained by prolonged vomiting causing a loss of hydrochloric acid (stomach acid) and an increase of bicarbonate in the plasma to compensate for the lost chloride in hypokalaemic and hypochloraemic metabolic alkalosis. Initially, the urine has a low chloride and high bicarbonate content, reflecting the primary metabolic abnormality. However, bicarbonate is secreted along with sodium, and, over time, the patient becomes progressively hyponatraemic and more profoundly dehydrated. Because of the dehydration, a phase of sodium retention follows, and potassium and hydrogen are excreted in preference. This results in the urine becoming paradoxically acidic. Alkalosis leads to a lowering of the circulating ionised calcium, and tetany can occur.



27.14 Visible pylorus due to muscle thickening, in the left upper abdomen. ⏎



27.15 Signs in IHPS on an upper gastrointestinal tract contrast study. ⏎

Preoperative management

Management of IHPS begins with intensive fluid resuscitation. The initial management includes nil by mouth and siting an IV cannula, with IV fluids commenced after assessing the degree of dehydration.

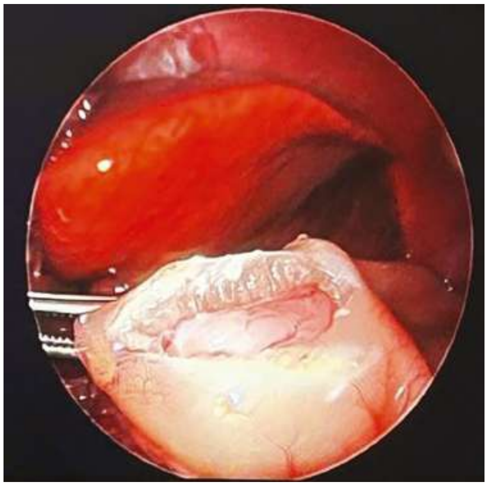
IV therapy includes sodium chloride 0.9% + glucose 5% + potassium chloride 20 mmol (per 1,000 mL bag of fluid). The fluid rate should include maintenance plus replacement of the calculated deficit over 24 hours. If a nasogastric tube is inserted, all gastric losses via the nasogastric tube are replaced with Hartmann's solution or sodium chloride 0.9% via a second infusion.

Blood gas analysis should be done 1 hour after conclusion of saline boluses, as, otherwise, erroneous values may occur. Depending upon the electrolyte values, repeated boluses may be given with 1 hour between each to allow tissue hydration, without causing unnecessary diuresis.

Chloride is said to be the most sensitive and specific indicator followed by bicarbonate (potassium levels are not useful). However, sodium and urine pH are also sensitive guides in cases in which chloride values may not be so easily available. Dehydration and hyponatraemia correction are key and prevent postoperative renal shutdown in these cases. In addition, it must be remembered that preoperative bicarbonate level needs to be kept below 30 mEq/L, as it poses a serious anaesthetic risk in the form of respiratory depression, due to decreased respiratory drive. After the fluid and electrolyte management and two consecutive normal blood gases, the patient is taken for surgery.

Surgical management

The surgical procedure of choice remains either an open or a laparoscopic Ramstedt's pyloromyotomy (Figure 27.16). In open surgery, a right supraumbilical transverse incision or circum-umbilical incision (Bianchi incision, which is a three-quarter incision in the superior skin fold of the umbilicus) is made, depending upon the choice of the operating surgeon. The peritoneal cavity is entered and the pylorus is delivered by gently pulling the omentum out. The pyloric olive is identified and an incision on the olive is made with a blade on the antero-superior wall of the pylorus. The incision is extended proximally to 0.5–1 cm on the stomach body and distally to the prepyloric vein of Mayo. Distally, there are increased chances of perforation due to the duodenal fornix, and care should be taken to try and avoid opening the mucosa. After incision, the muscles are cut and spread by using a Benson spreader or the back of mosquito forceps until the mucosa is exposed and bulges out. The completeness is checked by mobility wherein both upper and lower segments of the pylorus should move independently. Mucosal leaks are checked by filling the abdominal cavity with warm saline and asking the anaesthesiologist to push 20–30 mL of air via the nasogastric tube, looking for bubbles and the passage of gastric contents distally.



27.16 Laparoscopic pyloromyotomy. ⏎

Laparoscopy is an effective alternative, with lesser time to enteral feeds and better cosmesis, and essentially employs the same procedure using 3 mm instruments. The olive is incised with the coagulation current of a diathermy or an arthrotomy knife and the muscles are spread with a pyloric spreader or a grasper.

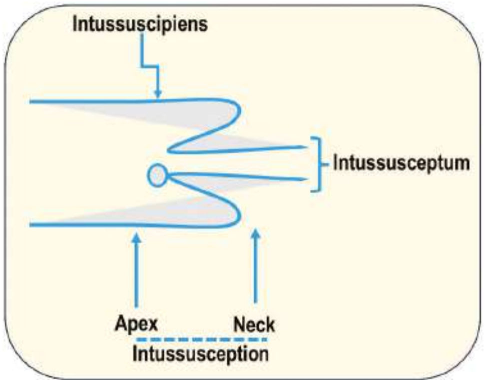
Postoperative management

Postoperatively, the feeding schedule is institution based, with some surgeons preferring to start 4–6 hours after surgery and others waiting up to 48 hours to allow the muscles to relax and prevent late-onset gastritis. In either regimen, feeds are gradually increased over 2–3 days using breast milk or formula, and patients are discharged within 3–5 days of surgery after establishment of full feeds.

Complications include duodenal perforation, which may go undetected. In such a case, mucosal leaks should be repaired and a pyloromyotomy should be performed in another part of the pylorus. Another complication is persistent vomiting, which may be due to postoperative ileus or due to an incomplete pyloromyotomy. Once adequately treated, IHPS does not recur and postoperative mortality is rare.

INTUSSUSCEPTION

Intussusception is the most common cause of intestinal obstruction in infants. It is the invagination of a bowel loop with its mesentery (intussusceptum) into



27.17 Diagram to illustrate intussusception. ⏎

the lumen of a contiguous portion of bowel (intussuscipiens) because of peristalsis or dysrhythmic contractions (Figure 27.17).

More than half of intussusceptions occur in infants younger than 1 year old. Intussusception is rare in infants younger than 3 months old and in children over 6 years of age. The male-to-female ratio is approximately 2:1.

Intussusceptions are classified into five types according to location: ileocolic, ileo-ileocolic, enteroenteric (including jejuno-jejunal and ileo-ileal) and colocolic types. Ileocolic intussusception is the most common type of intussusception and is an invagination of the terminal ileum through the ileocaecal valve into the colon. Most cases in infants and young children up to the age of 3 years are idiopathic, and the cause for the intussusception may be hypertrophied lymphoid tissue in the terminal ileum, which acts as a lead point for the invagination. Some intussusceptions, especially in older children, appear to be a result of pathological lead points with the most common being Meckel's diverticulum; other lead points have also been described: polyps, tumour, lymphoma, duplication cysts, parasites, haematoma, vascular malformation, inflamed appendix and inverted appendiceal stump. Usually, lead points are found in children younger than 3 months of age and in children older than 5 years, with the incidence increasing with advancing age. Systemic conditions such as Henoch–Schönlein purpura, cystic fibrosis, Peutz–Jeghers syndrome, familial polyposis and nephrotic syndrome are described as predisposing factors of intussusceptions. The invagination of the terminal ileum into the colon causes obstruction, blood vessel compression and consequent ischaemia. As a result, typical clinical symptoms include abdominal pain (present in 80–95%), vomiting and bloody stools (described as 'redcurrant jelly' due to the mix of blood and mucus). If intussusception is long lasting, perforation occurs.

Radiology has a key role to play in the diagnosis and treatment of intussusception. Ultrasound is the preferred imaging modality for diagnosing intussusception.

Management

For intussusception reduction, non-operative fluoroscopy-guided pneumatic enema and ultrasound-guided hydrostatic enema are equally dependable and safe techniques with high success rates. Intussusception reduction is defined as the release of the telescoped bowel. Operative reduction refers to the procedure by laparotomy or the more recent laparoscopic reduction.

Non-operative reduction Fluoroscopy-guided pneumatic enema and ultrasound-guided hydrostatic enema are equally dependable and safe techniques of non-invasive ileocolic intussusception reduction. Pre-reduction antibiotics may be given.

The presence of a surgeon at the time of reduction facilitates reduction and decreases morbidity by quick diagnosis and transport in patients who develop pneumoperitoneum from high-pressure enemas. Good IV access and proper fluid resuscitation are prerequisites prior to reduction. Waiting for an interval between 30 minutes and 4 hours is likely to be safe for repeated attempts at delayed enema reduction.

In patients older than 3 years presenting with intussusception, the possibility of a pathological lead point should be raised. The optimal length of observation after enema reduction of ileocolic intussusception appears to be 4 hours, based on the current data. Children with fever or a pathological lead point may have a higher risk of recurrence following enema reduction for intussusception.

Operative reduction Operation is indicated in uncorrectable shock, suspected bowel necrosis/perforation, peritonitis, irreducible intussusceptions and the presence of pathological lead points (or when they are suspected). Children with evidence of peritonitis, sepsis or free air on abdominal radiographs are not candidates for enema reduction. These children should be stabilised first and then treated surgically. Multiple recurrences are not a contraindication to attempt enema reduction.

Indications for bowel resection are perforation of the bowel, necrotic bowel, likely or actual irreversible ischaemia of the bowel, the presence of a lead point such as a Meckel's diverticulum and operatively irreducible bowel. Practically, there may be occasions when it is difficult to judge whether the ischaemia of the bowel is reversible or not. If there is doubt as regards the reversibility of the bowel ischaemia, it may be safer to resect and anastomose the bowel.

Surgery may be performed laparoscopically or open, depending on the skill and experience of the surgeon and available resources. Regardless of the approach, the intussusception must be successfully identified and then carefully reduced. In a laparotomy, the standard surgical technique uses a midline/right supraumbilical transverse incision. Despite the typical urgent or emergent nature of these cases, infection prevention measures should be utilised. The key to successful manual reduction is slow constant pinching and squeezing of the most distal part of the intussusceptum, just like squeezing a tube of toothpaste. The intussusceptum is milked in retrograde fashion out of its surrounding intestinal trap. To aid with the reduction, the intussusceptum is gently and slowly pulled out of the intussuscipiens. It is essential to perform both the retrograde milking and the gentle pulling slowly and steadily to increase the intraluminal pressure, just like the enema does. It should be performed without interruption until the reduction is completed. The index finger can be used to gently create a wider space between the intussuscipiens and intussusceptum and to break any airlocks (modified Hutchinson manoeuvre). The experience of the surgeon plays a significant role in manual reduction. Small serosal tears during reduction are acceptable and can be repaired if necessary. In the case of ileo-ileocolic intussusception, the ileocolic component is reduced first, followed by the remaining ileo-ileal component. After successful reduction, the previously intussuscepted bowel may look quite congested, bruised and possibly not viable. The leading edge of the intussusceptum may look particularly ischaemic. In almost all cases, the bowel will become pink and vital after application of warm saline towels for 5–10 minutes.

For laparoscopic surgery, a 5–10 mm periumbilical incision is made; this incision may ultimately be used for specimen extraction and for construction of the extracorporeal anastomosis if needed. Pneumoperitoneum is then established, and two additional 5 mm ports are placed, one in the left lower quadrant and the other suprapubically (in the case of enteroenteric or ileocolic intussusception). This port placement allows excellent access to the entire small bowel, the caecum, the ascending colon and proximal half of the transverse colon, the ileocolic artery, the transverse colonic arteries and the root of the small bowel mesentery. All four quadrants of the abdomen and the pelvis are thoroughly explored. Suspicious fluid is sampled for culture and suspicious lesions are biopsied. Other ports are placed as needed depending on the location of the pathology. Atraumatic graspers (such as endo-Babcock graspers) are used to ‘run’ the small bowel in a retrograde manner, starting at the ileocaecal valve and using the hand-over-hand technique to carefully grasp the mesenteric edge, not the bowel wall. Resection and anastomoses may be done intracorporeally using a stapling device for the bowel and a stapler or energy device for the mesentery, or it may be brought out through an incision and dealt with extracorporeally.

Recurrence tends to occur from 6 hours up to 4 years after an initial episode of intussusception. The reported recurrence rates of intussusception after non-operative reduction vary between 8% and 15%, independent of the technique, while recurrence rates are 1–3% after operative reduction. Each recurrent episode of intussusception should be treated as if it was the first episode of intussusception, either after a previous successful non-operative reduction or after a previous successful surgical reduction. For recurrences of intussusception, a surgical reduction should be considered in the case of failure of non-operative treatment, a suspected pathological lead point or several recurrent episodes. However, there are no specific recommendations concerning how many recurrent episodes warrant surgical management. Studies suggest that a third recurrent episode of intussusception within a short period of time should be an indication for surgery because of a high incidence of a pathological lead point. Recurrences can successfully be managed with laparoscopy as well.

Outcomes

Morbidity is influenced by the time lapse between the onset of symptoms and diagnosis. Most of the patients have a favourable course if reduction is achieved within 24 hours from the onset of symptoms, after which there is an increased need for surgical intervention and associated surgical complications. Complications after laparotomy and laparoscopy for intussusception include common postoperative problems such as wound infection, fascial dehiscence and small bowel obstruction. Reported complication rates are lower (4%) when no enterotomy or bowel resection is performed (26% of cases). Mortality associated with intussusception is <1% in most parts of the world.

ACUTE TRAUMA SURGERY IN CHILDREN

The most common cause of death in children in developed countries is trauma. About 75% of trauma occurs on the roads, mainly blunt trauma, with most children sustaining multiple injuries. Although the principles of resuscitation of injured children are similar to those for adults, an appreciation of the differences in cardiorespiratory variables, airway anatomy, response to blood loss, thermoregulation and equipment required is essential for successful initial resuscitation. Cerebral, abdominal and thoracic injuries account for most of the disability and death among injured children.

The management of childhood trauma starts with a primary survey (advanced paediatric life support guidelines), which, after arresting major haemorrhage, addresses airway, breathing and circulation (ABC). This is followed by a secondary survey, which is a head-to-toe examination. A later tertiary survey can identify any missed or hidden injuries (Table 27.7).

Problems related to IV access are common due to ongoing shock and in smaller children, and this often leads to delayed and inadequate resuscitation of the injured child. Intraosseous access may be reasonably rapid and is an easy alternative in patients with difficult venous access, which is recommended mostly up to 6 years of age and is most commonly in the tibia.

In children, thermoregulation is a key component, as rapid heat loss occurs because of the larger body surface area in relation to weight and this may complicate shock or even render it refractory. The child's temperature should therefore be measured regularly, and an appropriate paediatric radiant warmer may be necessary to maintain body temperature when the child is exposed for the initial survey and resuscitation.

Any child who presents with hypotension secondary to hypovolaemia has usually lost at least 25% and sometimes as much as 50% of the total blood volume. Hence, the heart rate or pulse rate becomes much more important than the blood pressure. Additionally, in infants, shock may manifest as hyperventilation or hypoventilation, skin mottling, erratic cardiovascular measures, glucose intolerance or metabolic instability. In view of the difficulties in the clinical assessment of shock, urine output should be closely monitored, with the aim of >2 mL/kg/hour in infants and >1 mL/kg/hour in older children. As a general guideline, hypovolaemic shock is rarely attributable to head injury alone, except in children with large scalp lacerations, open skull fractures with dural sinus tears or hydrocephalus and severe intraventricular bleeding. In cases of shock, two boluses of normal saline are administered at 20 mL/kg 1 hour apart, followed by blood products according to a massive transfusion protocol. The Toronto protocol suggests that transfusion requirements of more than 40 mL/kg mandate operative intervention. Increased experience with the concept of observational management has indicated that the majority of haemodynamically stable children rarely need blood and can be safely managed with as little as 3 days of hospitalisation. With the evolution of more sophisticated diagnostic imaging, increasingly precise data have provided objective evidence that most splenic, hepatic and renal injuries would routinely heal, usually within weeks. So consistent has been the success of non-operative management that this approach is now considered the 'routine' standard of care.

Table 27.7 Steps in the management of childhood trauma ⏎

Step	Details
Primary survey	• Arrest major haemorrhage • Check ABC: airway, breathing and circulation • Stabilise cervical spine • Ensure IV or intraosseous access • Cross-match and transfuse if needed • Thermoregulation
Secondary survey	• Complete history and examination • Evaluate cause and effect • Look for allergies and take past history
Tertiary survey	• Identify missing injuries • Detailed examination and charting
Imaging	• Trauma series X-rays • Focused abdominal sonography in trauma (FAST) • CT depending upon haemodynamic stability and requirement
Further evaluation	• Triaging re-established • Observation • Admission/discharge if a minor

However, many paediatric trauma patients still need emergency surgical intervention, often requiring the coordination of multiple surgical specialties.[32] Those patients are at an increased risk of mortality, and delays in operative intervention have led to increased morbidity and mortality. Trauma series imaging involves radiographs of the cervical spine, chest and pelvis. If there has been a head injury, a CT scan may be needed. A CT scan provides optimal imaging assessment of abdominal injuries in the haemodynamically stable child. Oral and IV contrast is often used, as IV contrast helps to outline solid organs, and enteral contrast helps to assess for potential intestinal injuries.

The most common clinical decision to be made by the emergency trauma team is usually whether to do focused CT scans or a pan-CT involving the entire body; the latter may be the safer option in smaller children or non-verbal children.

In children, head injury is the most common, followed by injury to the extremities, with abdominal injuries being the third most common site. Head injuries in children are a leading cause of disability and death. At least 80% of children dying with multiple traumas have significant head injuries, compared with 50% of adults. To complicate matters, spinal cord injury should not be diagnosed or ruled out on basic radiographic evaluation alone, since up to 67% of children with a spinal cord injury have no radiographic abnormality. A CT scan or magnetic resonance imaging (MRI) may be needed to diagnose spinal cord injury.

Abdominal injuries are a frequent cause of accidental death in children. Compared with adults, children are more prone to abdominal injuries because they have a relatively larger abdominal surface area, more flexible ribs, a relatively flat diaphragm, thinner abdominal wall musculature, a square shape to the abdomen (becoming more rectangular with age), less abdominal fat and more anteriorly placed solid organs, and the urinary bladder is somewhat abdominal due to a shallow pelvis. Most commonly, blunt abdominal trauma may be very difficult to evaluate because physical findings may be minimal despite serious injury (e.g. bicycle handlebar injury to the upper abdomen, when a circular bruise is seen on the skin and the visceral injury may be a duodenal haematoma, bowel perforation or pancreatic injury). Concomitant injuries may divert attention from the abdomen.

The need to preserve the spleen in children, if possible, further complicates the management of abdominal trauma. Serial abdominal examinations are key, since the cardinal findings in cases of severe intra-abdominal bleeding are distension and tenderness. Occasionally, there is a scaphoid abdomen due to a traumatic diaphragmatic rupture. Sometimes, intraperitoneal blood may be evident after 24 hours as bruising in the loins (Grey Turner's sign) or around the umbilicus (Cullen's sign). Abrasions from seat belt injuries may indicate the force of the deceleration and suggest intraperitoneal damage is likely. Mesenteric bruising and intestinal ischaemia may underlie a lap belt abrasion across the lower abdomen, which may also raise intra-abdominal pressure and rupture the diaphragm.

Most patients with blunt abdominal trauma, and some with penetrating trauma, can be managed non-operatively. A laparotomy is required in only about 5% of cases and is indicated in haemodynamically unstable patients (with a transfusion requirement of 40 mL/kg or more within a 24-hour period), in penetrating injuries of the stomach, intestine or bladder or in rupture of the diaphragm.

In polytrauma situations, patients can die from intraoperative metabolic failure manifested by coagulopathy, hypothermia and metabolic acidosis (the triad of death). During protracted repairs, it is best to avoid early complex procedures such as formal liver resection or pancreaticoduodenectomy. Damage control surgery spreads the operative procedure into a multi-staged approach. For laparotomy, a midline incision is performed, and the four quadrants are packed, with inspection of each quadrant for injury in turn. The phases of damage control surgery are outlined in Table 27.8. Laparoscopy, accompanied by exploration of the local wound, can also be helpful in avoiding an unnecessary laparotomy in patients with a penetrating injury.

Table 27.8 Steps/Phases in damage control surgery

Step	Details	Example(s)
Phase I: short primary operation	Control bleeding Prevent contamination	Packing Stapling or oversewing of intestinal lacerations
Phase II: intensive care unit resuscitation	Transfer to the intensive care unit Ongoing resuscitation	Transfusion Sedation Pain control
Phase III: relook surgery	Definitive repair of specific injuries within 24 hours	Hepatic resection Distal Pancreatectomy Bowel resection

Interventional radiology includes diagnostic angiography and therapeutic embolisation, which may be helpful in ongoing bleeding in abdominal viscera. It may also help in percutaneous drainage of collections, such as urinomas or pseudocysts (size >5 cm or duration >4–6 weeks).

Thoracic injuries occur frequently, often in combination with head or abdominal injuries, and are associated with a high death rate. The elasticity and resilience of the chest wall make fractures of ribs and the sternum, or flail chest, less common than in adults. Severe parenchymal thoracic injuries may be present with minimal or no signs of external trauma. Thoracic injuries should be considered during the 'breathing phase' of the primary survey and some need prompt treatment. Important injuries are tension pneumothorax, massive haemothorax, open chest wounds and cardiac tamponade. Young children are prone to hypoxia, as they have a lower functional residual capacity and higher oxygen consumption per kilogram. Most thoracic injuries (around 85%) are due to blunt trauma, which includes road traffic accidents, falls from bicycles and falls from heights. Non-accidental injuries should be considered in infants and toddlers with rib (and other) fractures, variable ages of injuries or reported mechanisms of injury that do not fit with the findings.

A tension pneumothorax should not be missed on the primary survey. The key signs are severe hypoxia, shock, a hyper-resonant hemithorax, a shift of the trachea and the cardiac impulse, and decreased transmitted breath sounds. If not treated immediately, this can cause impaired venous return, vena caval kinking, hypotension and death.

Surgical emphysema and crepitus may be present, and they suggest that air is leaking from the pleural space into the subcutaneous tissues. Immediate needle aspiration in the second intercostal space in the midclavicular line is indicated. This should be followed by a tube thoracostomy with a large-bore chest tube into the fourth or fifth intercostal space in the mid-axillary line. A pneumothorax occupying more than 10–15% of the chest cavity usually needs a chest drain. If there is an open pneumothorax, the defect should be occluded immediately and a chest tube should be inserted, preferably at a different site. In haemothorax, there is dullness to percussion and decreased breath sounds, with evidence of shock and impaired ventilation. A chest X-ray may show fluid in the pleural space, an air/fluid level or a complete 'white-out'. In all of these cases, an intercostal chest drain should be placed immediately and a blood transfusion arranged. If bleeding continues, a thoracotomy may be required.

First and second rib fractures imply significant blunt force trauma and are associated with serious internal thoracic injuries. In 10th to 12th rib fractures, underlying liver, spleen or kidney injury should be suspected. In those under 3 years of age, child abuse (non-accidental injury) should be considered, if there is no plausible explanation for the injury. The management of rib fractures is mainly conservative with adequate pain relief to ensure comfortable breathing and deep-breathing exercises to prevent atelectasis and pneumonia. Similarly, management of lung contusions is by supportive measures including pain relief, breathing exercises and fluid restriction.

Traumatic asphyxia occurs almost exclusively in children because of their flexible thorax and the absence of valves in the superior and inferior vena cava. Direct, sudden compression of the compliant thoracic cage against a closed glottis causes a sudden dramatic rise in intratracheal and intrapulmonary pressures.

Depending upon the diagnosis at CT, solid organ injuries, except for grade IV/V or haemodynamically unstable patients, are managed conservatively, whereas hollow viscus injuries require abdominal exploration. Duodenal injuries are troublesome, as there may be a haematoma of the duodenal wall or a perforation. A perforation may be contained in the retroperitoneal space and may be difficult to diagnose. The majority of these can be managed conservatively with nasogastric aspiration and parenteral nutrition. If operative repair is needed, small fresh injuries can be closed and an omental patch and a drain considered, but larger injuries, in the presence of significant contamination, may need pyloric exclusion with a gastro-jejunostomy bypass to allow healing.

The most injured solid organ is the spleen. Most splenic injuries can be treated conservatively, and an initial non-operative approach results in an expected 95% spleen salvage rate, as most injuries are grade III or less (around 80%). In high-grade (e.g. grade IV/V) injuries with continued bleeding, the surgical options are total or partial splenectomy. If total splenectomy is needed, splenic auto-transplantation (e.g. in an omental pocket) should be considered. Surgical intervention should always aim to preserve the spleen to reduce the risk of overwhelming post-splenectomy infection. After a total splenectomy, antibiotic prophylaxis with oral penicillin V and vaccination with polyvalent pneumococcal vaccine within 24 hours of the emergency splenectomy are essential in children.

In liver injuries, damage control is the first priority, followed by haemostasis. Pringle's manoeuvre is a well-described measure of temporary vascular control by a sling or finger around the portal triad to stop the portal venous and arterial inflow. Caval or hepatic vein laceration/avulsion should be suspected if there is still significant bleeding from the injury site. Direct suture using horizontal mattress sutures, an argon beam coagulator, topical agents (e.g. Surgicel, fibrin glue) and absorbable mesh (e.g. Dexon, Vicryl) may be helpful in these cases. On some occasions, the bleeding is so profuse that perihepatic packing with large operative gauze packs compressing the right upper quadrant and closure of the abdomen is the only possible option. Later (usually after 24 hours), the packs are removed and further attempts to control the bleeding are planned. Intervention procedures such as embolisation may be used in addition to the packing in acute bleeding. Embolisation may also be used as a definitive treatment for a pseudoaneurysm.

Overall, the general rules for managing isolated liver or spleen injuries non-operatively is watchful waiting, serial haematocrits, admission to hospital according to injury grade (e.g. splenic injury grade II usually requires 3 days of hospital stay), intensive care unit admission for higher grade injuries and activity restriction for an injury above grade II, with no recommended need for pre- and post-discharge imaging if the child is stable (according to American Pediatric Surgical Association guidelines).

The majority of kidney trauma is also blunt trauma, and about 95% of these cases can be treated conservatively. Microscopic haematuria following abdominal injury is common, but frank haematuria should be promptly investigated with a CT scan. Frank haematuria may result from underlying renal anomalies such as pelvi-ureteric junction obstruction or a renal tumour. Patients should be observed in hospital until frank haematuria resolves. Usually, the injury involves parenchymal contusions, but injury to the pelvi-ureteric junction or the vascular pedicle may occur. A relative lack of perirenal fat is a predisposing factor to renal injury in children. Surgical (or radiological) intervention may be required in 5% of cases with renal trauma (e.g. expanding retroperitoneal haematoma, vascular pedicle injury or urinoma). On surgical exploration, total nephrectomy is often needed but partial nephrectomy may be possible for parenchymal lacerations.[33]

The psychological effects of childhood trauma may pose long-term problems; these need close follow-up and are often overlooked in the attempt to manage the child's injuries. In addition, child abuse or non-accidental injury must always be considered, as it is not evident in all cases, and there is a tendency for repeated attacks. It must be suspected in cases with less plausible mechanisms of injury.

Abusive head trauma or shaken baby syndrome is the leading cause of severe brain injury and death in children younger than 2 years. Early recognition of abusive head trauma can be life saving. Abusive head trauma can result in a variety of injuries, ranging from intracranial haemorrhages to complicated skull fractures and spinal injuries. Infants with multiple types of head injuries should therefore be carefully evaluated for the possibility of non-accidental injury or trauma. Abdominal injuries in non-accidental injury are difficult to identify, and there can be significant delay in diagnosis. If there is a concern about child abuse and possible abdominal symptoms, there should be a low threshold for obtaining an abdominal CT scan. Additionally, when children present with suspicious fractures (<6 months old with any fracture, classic metaphyseal lesion or posteromedial rib, scapular, spinous process, sternal or femur fractures) or findings suggestive of non-accidental injury (e.g. head injury or suspicious bruising), full non-accidental injury evaluation should be performed, including a skeletal survey to rule out occult fractures. Children with central bruising, especially on the face and neck, human bites without an appropriate history, or burns consistent with immersion or branding are red flags for non-accidental injury and child abuse.

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